Department of ENERGY, MINES and RESOURCES
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INTRODUCTION

The Department of Energy, Mines and Resources is the federal government's principal agency for the discovery, investigation, development, and conservation of the nation's mineral, water and energy resources. To better fulfill this task, the Department (previously known as the Department of Mines and Technical Surveys) was considerably broadened and reorganized by Act of Parliament (Government Organization Act, 1966, 14-15 Elizabeth II, Chapter 25), which came into force on October 1, 1966.

Most significant among the changes were (1) the acquisition from the former Department of Northern Affairs and National Resources of water resources inventory and planning, and the administration of mineral exploration in certain areas under federal jurisdiction, including Hudson Bay and the continental shelves off the Atlantic and Pacific coasts; and (2) the newly-created function of studying, recommending and co-ordinating federal policies related to energy development. The staff of the Department now numbers around 4,000.

Taking account of its new responsibilities, the Department underwent considerable internal reorganization. Its operative agencies were distributed among four large units or "groups": Mines and Geosciences, Water, Mineral Development, and Energy Development. Each of these groups is in the charge of an assistant deputy minister reporting to the deputy minister.

The Mines and Geosciences Group retained most of the older branches -- Surveys and Mapping Branch, Geological Survey of Canada, Mines Branch, Observatories Branch, Polar Continental Shelf Project, and Geographical Branch -- and is consequently considerably larger, in personnel, than the three other groups combined. The Water Group contains the Marine Sciences Branch, plus two new branches -- Inland Waters, and Policy and Planning. The latter two branches were still in a process of formation and consolidation during the period under review, and the Inland Waters Branch is covered under its two former organizational headings, Water Resources and Water Research. The Mineral Development Group contains the Mineral Resources Division and the Explosives Division, both units having been taken over from the old Department.

The Energy Development Group contains no pre-existing units, and was not yet in operation during the period covered here. It will, therefore, not be covered under a separate heading in this report. An Assistant Deputy Minister (Energy Development) was appointed in June 1967, and recruitment of professional staff was expected to begin in 1968. The Group's function will be to collect information and to make recommendations to the Minister on energy matters and energy policy, in co-operation with the several Crown companies and agencies in the energy field. It will also examine the various forms and sources of energy -- coal, oil, gas, hydro-electric and nuclear -- and work towards effective co-ordination and implementation of energy policies. Examples of such federal efforts in the field of electricity are the participation, with the provinces of Nova Scotia and New Brunswick, in the study of the tidal power potential of the Bay of Fundy; the federal-provincial agreement on the Nelson River power development whereby the federal government will build a 600-mile transmission line costing $170 million and lease it to Manitoba Hydro; participation in the control bodies for the proper implementation of the Columbia River Treaty; and the study of the proposed trans-Canada transmission grid.

The functions of the other three groups need not be described here, since their work is dealt with comprehensively under the various branch headings which follow. Several new developments, however, may be noted.

The Canada Centre for Inland Waters was under construction at Burlington, Ontario, whose special field of study will be the Great Lakes, with emphasis on pollution abatement. The Department's water-quality laboratory for the Maritime Provinces was moved from its temporary quarters at Dartmouth, N.S., to its permanent establishment at Moncton, N.B. The Bedford Institute of Oceanography at Dartmouth announced plans for a $2.5 million expansion that will practically double its capacities over the next five years. The new Institute of Sedimentary and Petroleum Geology at Calgary, constructed at a cost of $2.5 million, with a planned staff strength of 100, began its work. A new geomagnetic laboratory for the Observatories Branch was under construction in Ottawa; the total cost was to be $1,250,000. A new spectograph was built for the 72-inch telescope in Victoria, B.C., and was expected to double the instrument's efficiency. Three new survey-and-research ships were under construction and six high-speed launches were purchased for the Marine Sciences Branch. The Department also co-ordinated federal preparation for the important National Conference on Pollution and Our Environment which was held in Montreal in November 1966 and produced numerous guidelines on the abatement of water, air and soil pollution.

By far the largest part of the Department's work is not of the type that causes headlines or can be summed up in a sentence. It is rather the steady accumulation by patient and dedicated effort of bits of scientific and technical information. This information, analyzed, combined and published in many ways, provides a progressive and ever-broadening base for the resource development of Canada.

One detail about this report itself deserves mention. While previous annual reports of the Department covered calendar years, future reports will cover fiscal years, i.e., from 1 April to 31 March. To provide for this transition, the present report covers the period 1 January, 1966, to 31 March, 1967.

MINES AND GEOSCIENCES GROUP

Demands on the services provided by the Surveys and Mapping Branch continued to expand in all its activities. There was a substantial increase in map production, and the new series of the federal electoral maps was completed. Receipts from the sale of maps and charts increased by 12 per cent, producing a revenue of over $380,000. Orders and sales by the National Air Photo Library accounted for a revenue of $260,000. A Branch regional office was opened in Fredericton, New Brunswick.

The Geodetic Survey had 20 parties in the field extending and strengthening the national survey framework. Close co-operation has been maintained with the United States Coast and Geodetic Survey on the Satellite Triangulation Program. Investigation in long-range studies on crustal movement is continuing. The Topographical Survey again employed its airborne electronic positioning equipment, called aerodist, in its resource mapping north of the prairies. An increased workload for this division has been occasioned by the Mapping and Charting Establishment of the Department of National Defence phasing out of domestic mapping. The Legal Surveys and Aeronautical Charts Division staffed 17 field parties on legal surveys of public lands. The northern boundaries of Manitoba and Saskatchewan were completed as well as the northern portions of the boundary between the two provinces; legislation concerning these demarcation lines was presented to and ratified by Parliament. Two new series of aeronautical charts were produced in addition to the heavy commitment for both civilian and military agencies.

The Interdepartmental Committee on Air Surveys produced aerial photography to meet the demands of 11 federal departments and agencies. Experimental work on colour photography continued.

The Branch continued to provide technical advice to the External Aid Office in connection with air-survey projects in certain developing countries. Senior Branch officials represented Canada at a number of international meetings including the International Geodetic Conference, Directing Council of the Pan-American Institute of Geography and History, International Society for Photogrammetry and the Fifth United Nations Regional Cartographic Conference for Asia and the Far East in Canberra, Australia.

The annual meeting of federal and provincial survey directors was held in Victoria, B.C. The National Advisory Committee on Control Surveys and Mapping sponsored a map-users' conference and in co-operation with the Canadian Institute of Surveying sponsored a symposium on Survey Education. The Interdepartmental Committee on Air Surveys sponsored an air-photo interpretation symposium in Ottawa which was attended by over 200 experts in that field.

GEODETIC SURVEY

Twenty field parties extended or strengthened horizontal and vertical control to provide a national framework for mapping, charting, and major engineering projects. In addition, the Geodetic Survey participated in the Satellite Triangulation program in co-operation with the United States Coast and Geodetic Survey, and continued work on several investigational projects.

The extension and strengthening of the network of first-order horizontal control was carried on in the Northwest Territories and eight provinces. In the Northwest Territories and northern Manitoba a triangulation arc was extended westward along the 60th parallel from the Hudson Bay coast to a point 40 miles east of the Manitoba-Saskatchewan boundary. In British Columbia small triangulation networks were established in the Hudson Hope and Campbell River areas. At Campbell River a strong network was established, connecting Vancouver Island to the mainland; this network will provide a basis for a long-term investigation into suspected horizontal crustal movement in this area. A number of lines were measured by geodimeter and tellurometer to provide scale control in existing networks between Campbell River and Vancouver. In Alberta first-order control for municipal surveys was established in the Greater Edmonton area. The Geodetic Survey co-operated with the Topographical Survey in the establishment of a first-order aerodist network which extends eastward from existing triangulation, north and east of Edmonton, across Saskatchewan to Lynn Lake, Manitoba. In Saskatchewan the Medicine Hat-North Battleford arc was completed. In northern Manitoba an arc of triangulation and first-order traverse was extended south from the 60th parallel to Churchill and Cape Churchill.

In Ontario and Quebec a large network was established to provide first-order control for municipal surveys throughout the Ottawa area. Control for municipal surveys was also established at North Bay and throughout the Niagara Peninsula. The triangulation arc in northern Quebec was extended west and south from Sugluk to the vicinity of Port Harrison. In Newfoundland satellite triangulation stations at St. John's and Goose Bay were connected to existing networks.

The Canada-United States Satellite Triangulation Program continued at Lynn Lake (Manitoba), Cambridge Bay and Frobisher Bay (Northwest Territories), Timmins (Ontario), Halifax (Nova Scotia), St. John's (Newfoundland), and Goose Bay (Labrador). All operations were terminated in June.

First-order levelling operations were carried out in four provinces and the Northwest Territories. In the Northwest Territories a line was run from Yellowknife to Enterprise. In British Columbia a line from Vancouver to Kamloops was re-levelled together with three branch lines to Iona Island, to Ladner and along Steveston Jetty. In Alberta, municipal control was established in Edmonton and Calgary. In Ontario, municipal control was established in part of the National Capital Commission area including Ottawa, and a portion of an old line along the Welland Canal was re-levelled. In Quebec the line along the railway from Hervey Junction to Senneterre was re-levelled together with the line from the Lake St. John area to La Passe Dangereuse and Lac Rouvray. The results of the re-levelling verify the crustal uplift associated with the Lake St. John area. An inspection party checked some 800 bench marks in the area south of Montreal and Quebec. Precise astronomical latitude and longitude was determined at 45 triangulation stations to be used for investigational work at 15 points in British Columbia, 12 in Alberta, 3 in Manitoba, 6 in Ontario and 9 in Quebec.

The elevation and position of a Goddard Space Centre Satellite Camera at Laurentian University, Sudbury, Ontario were determined.

In the laboratory, development and improvement of electronic and radio equipment continued. All divisional electronic and radio equipment is maintained by the laboratory. New electronic-computer programs, to analyze our data and to process the aerodist field results, have been developed.

During the past 15 months the Geodetic Survey continued its interest in international geodetic organizations. Staff members attended several meetings and seminars in Canada and the United States.

TOPOGRAPHICAL SURVEY

The Topographical Survey has maintained a high level of map production and in the fifteen months covered by this report has cleared for reproduction 30 maps at the 1:25,000 scale, 403 at 1:50,000 and 73 at 1:250,000, for a total coverage of 352,500 square miles.

Early in 1966 the Mapping and Charting Establishment (previously the Army Survey Establishment) of National Defence declared its

intention of discontinuing domestic mapping, except for strictly military needs, and in succeeding months turned over to Topographical Survey almost its entire 1:50,000 mapping program including about 150 sheets of completed compilations. It is however carrying to completion the 1:25,000 and 1:250,000 mapping that had already reached compilation stage.

The Topographical Survey has therefore been obliged to revise its field and compilation scheduling to accommodate the priority elements of the former two parallel programs. In future, this Division will be responsible for the production of new mapping at the 1:25,000 and 1:50,000 scales and the maintenance of all mapping at the three scales: 1:25,000, 1:50,000, and 1:250,000.

The Mapping and Charting Establishment has for many years accepted and under agreement has published the 1:50,000 mapping produced by the British Columbia Department of Lands, Forests and Water Resources. This work will also be taken over by the Topographical Survey.

Complete map coverage of Canada in 1967 at the 1:250,000 scale appears probable. There will be a continuing program of revision after the series of 925 maps is complete.

About 7,250 maps at the 1:50,000 scale are now available for distribution, representing 33 per cent of the land area of Canada. Another 500 maps at the 1:25,000 scale cover the major cities. Distribution of advance information prints of new mapping amounted to 1,000 prints per month.

Field work engaged 36 field officers and six office personnel in a wide variety of surveys and map inspection across Canada.

An air-supported party secured control for 1:50,000 mapping of 13,000 square miles required by the Geological Survey in northern British Columbia and in southwestern Yukon.

Several field parties obtained control for 1:25,000 mapping at Halifax, Moncton, Sept Iles, Simcoe, and Leamington and for special airport plots at Gander, Newfoundland, and at North Bay, Sudbury, and Timmins, Ontario.

More cities are requesting co-ordinate control surveys and monumentation for municipal use. This year the Division assigned seven field officers to this type of work who undertook surveys in co-operation with municipal engineers in St. John's, Corner Brook, Halifax, Dartmouth, Sydney, Ottawa, Orillia, the city complex west of Toronto, and in Regina, Calgary and Edmonton. This work was extended to provide control surveys for new express highways and the twinning of the Welland Canal in southern Ontario. Reconnaissance was carried out in Vancouver in preparation for a co-ordinate survey of that city in 1967.

Three field parties carried out spirit levelling surveys for engineering and mapping purposes. In the winter of 1966, one party established levels along the Churchill River (Newfoundland) for 200 miles from tidewater to Churchill Falls; another party, under the same officer, in 1967 extended levels for 355 miles in Ungava between Schefferville and Lac Bienville. The third party continued the joint federal-provincial levelling program in Saskatchewan and established second-order levels in the industrially developing areas around Quill Lakes and Yorkton.

Five field officers were assigned to surveys for revision and/or field completion of 1:25,000 and 1:50,000 mapping in Nova Scotia, New Brunswick, Quebec and Ontario; some members of the office staff of the inspection subsection were also engaged in these projects on a rotational basis.

Assistance to other organizations included determination of positions for 50 radio aids to navigation across Canada for the Department of Transport, and surveys for the Polar Shelf Project in the Arctic Islands.

Much progress was made in the processing, evaluation and cataloguing of survey data by computer. New ground had to be broken in digitizing aerodist data for computer processing. The resulting files and catalogues are available to, and being widely used by, other survey and engineering organizations.

With completion of the 1:250,000 mapping in sight, emphasis in compilation returned to the 1:50,000 scale. Production has not shown an increase over the previous year but reorganization of staff, replacement of obsolete equipment and training are expected to show early returns. Map revision work consisted of recompilation of about 70 sheets in the Eastern Townships of Quebec, around Ottawa. and southwest of Calgary.

The demand for special plots at larger than mapping scales continued to increase. In this reporting period, there were 41 special projects varying from a few days' work to major mapping tasks for many branches of this department, for the departments of Indian Affairs and Northern Development, Public Works and Transport and for Atomic Energy of Canada, Defence Research Board, National Capital Commission and the Arctic Institute of North America. Of particular interest were the mosaics and special plots, produced from several sets of aerial photography, of the surging Steele Glacier in the Yukon. In addition, technical advice and assistance was extended to many agencies in preparing specifications for map compilation by contract.

The Topographical Survey continued to inspect the aerial photography carried out by contract for the federal government, advised on specifications and recommended payment for acceptable work.

The Technical Assistance Unit continued to monitor the surveys and mapping carried out by the External Aid Office under the Colombo Plan, Special Commonwealth African Assistance Plan and the Canada-Commonwealth Caribbean Assistance Program. Countries now involved are Trinidad, Guyana, Nigeria and Tanzania.

The Research and Development Unit provided electronic computer programs for control plotting and manuscript drawing, adjustments for aerotriangulation control extensions, adaptation of existing and new equipment parameters into the adjustment program, the adjustment of common points along aerotriangulation block edges, and adjustments of special test projects. In addition, the unit assessed photogrammetric block adjustment of foreign-aid mapping, accuracy assessment of plotting equipment, and problems encountered in the processing systems of different computers.

Several possible approaches to automated mapping systems were investigated and these studies will intensify throughout the coming year.

The photographic laboratory of the unit was established late in 1966. Experimental work was directed toward map revision, map substitutes and map supplements.

LEGAL SURVEYS AND AERONAUTICAL CHARTS

Legal surveys in Indian Reserves, national parks and territorial lands were undertaken as usual. Of particular note were subdivision surveys at several settlements in the Northwest Territories. All work connected with the north boundaries of Manitoba and Saskatchewan, and the northern part of the boundary between Manitoba and Saskatchewan was completed. Legislation establishing these boundaries as surveyed by the respective boundary commissions was presented to and ratified by Parliament. New types of aeronautical charts continued to be required to support new developments in electronic aids to navigation and to assist aviators and air-traffic controllers.

Five interprovincial and territorial boundary commissions were active in the 15-month period from January 1, 1966. In addition to the work mentioned above, the report for the north boundary of

British Columbia was completed and preparation for legislation to ratify this boundary was initiated. The report of the inspection and restoration of the north boundary of Alberta was completed. The surveys to demarcate the unsurveyed portions of the Manitoba-Saskatchewan boundary were completed, and preparations were begun to resurvey the southerly 240 miles of this boundary.

Seventeen field parties carried out legal surveys in the public lands of Canada. In addition, contracts were arranged with 11 survey firms in private practice for government surveys, and technical instructions were issued for 308 legal surveys on Crown Canada lands for private and provincial agencies. Surveys were undertaken in 60 Indian Reserves, the largest project being the survey of the boundaries of a 63,000-acre new reserve for the Lac La Ronge band of Indians in northern Saskatchewan. The program of establishing local co-ordinate control networks for legal surveys was continued. One network was established at Banff townsite and two others in the Yukon Territory -- one at Hunker Creek, and another at Vangorda Creek, where 14,000 claims had been staked following the discovery of rich mineral deposits. In the Northwest Territories a new townsite at Wrigley and an addition to Inuvik were surveyed. Subdivisions for administrative staff and Eskimo settlement were carried out in the Arctic at Cambridge Bay, Gjoa Haven, Spence Bay, Igloolik, Hall Beach and Broughton Island.

Significant advances were made in aeronautical charting. Two new series of charts were produced -- one to inform aviators of standard instrument departure procedures and the other to provide information for traffic controllers at busy airports. A plotting chart at the scale of 1:6,000,000 was also produced to provide aviators with a suitable chart extending from the west coast of Canada to the coast of Europe. To facilitate military jet air operations, the high-altitude instrument approach procedures charts were published in bound book form rather than loose leaf as formerly, and were issued every 35 days.

Survey documents entered in the Canada Lands Surveys Records consisted of 556 plans and 200 field books. About 35,300 document extracts, publications and astronomical field tables were dispatched, and information on 398 airline distances was provided for official purposes.

The Board of Examiners met eight times. Of the forty-eight candidates examined in February 1966, nine qualified for the certificate of preliminary examination and six for commissions as Dominion Land Surveyors. Of the thirty-eight candidates examined in February 1967, eight were successful in their preliminary examinations, five qualified for Dominion Land Surveyor commissions and one completed the first part of the final examination to qualify as a Dominion Topographical Surveyor.

INTERNATIONAL BOUNDARY COMMISSION

The International Boundary Commission continued the annual maintenance required for the effective definition and marking of the 5,525 miles of boundary that divides Canada and the United States. Various parts of the line were inspected and three Canadian field parties, as well as parties from the United States, carried out maintenance on widely scattered sections.

The Commissioners for Canada and the United States made joint inspections along the line and inspected the work of field parties on the boundary between New Brunswick and Maine, Quebec and Maine, and Manitoba and North Dakota.

A Canadian field party working on the New Brunswick-Maine boundary inspected 166 monuments and relocated 1 monument at a highway crossing. In addition, herbicides were applied to maintain a cleared vista on 44 miles of boundary. The same party measured 109 lines with geodimeter on 37 miles of the Quebec-Vermont boundary, and inspected 115 monuments on that section.

A second Canadian party recleared 23 miles of the height-of-land boundary between Quebec and Maine, treating it with herbicide. On this section 553 boundary monuments were inspected, two of these were repaired and 12 monuments were replaced. In addition, this party established 6 new triangulation stations and measured 11 lines with geodimeter on the Detroit River, a continuation of a resurvey undertaken the previous year. Positions of buoys marking the boundary through western Lake Erie were also checked.

A third Canadian party made resurveys on the 49th parallel for the re-establishment of ornamental monuments at border road crossings from Manitoba westward to central British Columbia. Precise distance measurements were made with geodimeter to assist a United States party of the Commission in North Dakota. In all 17 new monuments and marks were installed and 18 lines measured.

An aerial application of herbicides was made on a 20-mile section of the boundary south of Trail, B.C., to maintain the cleared boundary vista.

During the 1966 field season, Canadian parties recleared 23 miles of boundary vista, treated 87 miles of boundary by chemicals (of which 20 miles were by aerial application) measured 138 lines with geodimeter, inspected 834 monuments (of which 3 were repaired), and re-established 30 boundary monuments.

MAP COMPILATION AND REPRODUCTION

Map and chart production for the last 15 months was slightly higher than for the previous 15-month period.

Maps received from the Topographical Survey for reproduction numbered 511. These included 32 at 1:25,000 scale; 395 at 1:50,000; and 84 at 1:250,000.

Maps received from the Mapping and Charting Establishment for plating and printing numbered 140. These included 29 at 1:25,000 scale; 56 at the 1:50,000 scale; and 55 at the 1:250,000 scale.

Maps and charts printed numbered 5,534. Of the total, 2,996 were printed on the large offset presses and 2,538 on multilith.

In the spring of 1967, the status of the 1:50,000 series stood at 28.3 per cent published for 6,175 sheets of a potential 21,800. The status of the 1:250,000 series stood at 88.9 per cent published, or 821 of a potential 923.

The conversion of the eight-mile series to 1:500,000 was 85.4 per cent complete, with 188 maps.

NATIONAL AIR PHOTO LIBRARY AND MAP DISTRIBUTION

National Air Photo Library

During the period under review, 5,880 requisitions for photographic work, the highest annual total in the Library's history, were prepared for processing. These requisitions covered 537,829 reprints from federal government air-survey negatives (contact prints, enlargements, multiplex diapositives, mosaics, lantern slides, etc.).

The Library received 60,803 new photos, bringing the total of the Library collection to well over three million.

In addition to the air-photo requirements of the various federal government departments, the Library fulfilled requests from provincial government departments, municipalities, exploration and development companies, educational institutions, religious groups, publishing firms, professional societies, and private individuals.

The sixth edition of the Air Photo Coverage Map of Canada (1965) was made available for distribution in April 1966. Copies are supplied, free of charge, on request. In addition, four supplementary sheets were compiled to show, in the same manner as the national coverage, the available photography held by those provinces which had not stored their negatives with the N.A.P.L. It is intended that this supplement to the national coverage will be compiled and issued annually.

A brochure, presenting a brief outline of the history of the Library, and containing information regarding requests and photographic material, first published by the Queen's Printer in December 1962, required a fourth printing. Approximately 30,000 copies of this brochure have now been distributed to the public, either by mail or through various government agencies.

Progress continued on the program to copy, on 70-mm film, some 800,000 prints from nitrate-base negatives. Over 200,000 prints have been copied to date. The purpose is to preserve this pictorial history of Canada accumulated between the years 1920 and 1940.

The National Air Photo Library will maintain a branch office in the new Geological Survey of Canada building in Calgary and distribute air photos covering the four western provinces, Northwest Territories, Yukon, and the Arctic Islands.

The Library has undertaken to store present and future negatives of the Newfoundland Forest Inventory, and to distribute prints.

Mail was received from over 50 universities, and 14 nations.

Map Distribution

During the past 15 months, the distribution of civilian and military maps was combined in a single Map Distribution Office. This involved considerable reorganization and expansion.

The number of maps distributed rose from 1,236,219 in 1965 to 1,485,906 in 1966, and total revenue increased from $258,757 to $301,262.

The stationing of Canadian troops in many parts of the world has necessitated a steady expansion of the section for foreign maps and charts. The section now has 12,572 maps and charts, an increase of 1,398 from the preceding year. It is the only depot for foreign maps and charts in Canada.

Since August, 1966, large map orders for federal and provincial government departments are no longer sent free of charge, but are sold with a 70-per-cent discount.

Geological Survey of Canada

The Geological Survey conducts investigations designed to add to the understanding of the geology of Canada and to contribute to advances in earth sciences. Its functions include preparing an inventory of the potential mineral resources of Canada; providing industry and government with the data needed for the discovery and exploitation of the nation's mineral deposits; providing data essential for proper planning and development of various resources; research that will contribute to an understanding of the formation of rocks and mineral deposits thus enabling geologists to assist even more effectively in prospecting for mineral deposits; developing instruments and methods as aids to both geological and mineral-deposit investigations; and assisting in field and laboratory training in the geological sciences and in the supporting techniques to meet the requirements of both science and the nation for trained personnel.

In 1966 the Survey provided support for 20 doctorate-theses projects through summer employment. A total of 72 graduate assistants were employed in the field and 41 in the office; 114 student assistants worked with various field parties and 54 were assigned to office positions.

The Geological Survey conducts a broad category of investigations of a regional nature in the Canadian Shield, in the Appalachian and Cordilleran geosynclinal belts, in the sedimentary basins of the Arctic Archipelago and the Interior Plains, and in the unconsolidated Quaternary deposits. In addition, activities directed toward the investigation of specific topics are undertaken, commonly as a result of the interest generated by the broader regional studies.

During the period covered by this report the Survey sent out 102 full-time field parties and 36 short-term parties. Twenty parties were active in reconnaissance studies, the remainder in more detailed mapping or in the investigation of specific topics. Although no major airborne reconnaissance projects were carried out, helicopters and light fixed-wing aircraft were used by many parties. Operation Selwyn, using a helicopter, continued reconnaissance mapping in eastern Yukon and adjacent areas; helicopter support was also provided to parties in central British Columbia and District of Mackenzie.

On a more detailed and topical scale the Geological Survey activities covered a wide range. Many of these projects were based on information derived from previous reconnaissance studies. More than 80 field parties were engaged in studies of this nature; the subjects studied ranged from ultramafic rocks in Yukon Territory to Cambrian biostratigraphy in the Canadian Cordillera; from relatively recent volcanic rocks in northern British Columbia to the uranium content of Saskatchewan lignites; from organic growths in carbonate tongues to the Manicouagan circular structure in Quebec. Laboratory studies ranged from the development of new geophysical instruments such as an ultra-low-frequency resistivity-probing device for Pleistocene and aquifer mapping or the adaptation of the rubidium-vapour airborne magnetometer for use as a practical and economical survey instrument, to mineralogical studies of nine new minerals and refinement of Rb/Sr age-determination techniques. Chemical analyses of 2,244 samples were completed, 1,959 spectrographic determinations were made and a total of 81,603 analyses were made on rocks, minerals and ores.

To stimulate and support geological research in Canadian universities, grants by the Geological Survey were initiated in 1951. During the period covered by this report 85 grants totalling $150,000 were awarded to 20 universities.

The results of the Survey's scientific work are published in the form of memoirs, bulletins, papers and geological maps. During the fifteen-month period covered by this report 6 memoirs, 22 bulletins, 52 papers, 20 geological maps (apart from those used to illustrate the preceding reports) and 1 miscellaneous report were issued.

About 390,000 copies of maps and reports were distributed, 8,218 sets of mineral and rock chips were sold, and 70 special collections representing Canada's mineral industry were prepared for display in Canadian embassies throughout the world.

The Geological Survey library, the most extensive of its kind in Canada, had a circulation of 61,174 items during the report period.

In addition to the headquarters in Ottawa, the Survey maintains offices in Calgary, Whitehorse, Yellowknife and Vancouver. The Calgary offices were moved in March to the Survey's new Institute of Sedimentary and Petroleum Geology building, officially opened in September 1967.

Several staff members are among the scientists from the United States and six other countries who have been selected as principal investigators by the U.S. National Aeronautics and Space Administration to conduct experiments on the first samples from the moon's surface to be brought back by United States astronauts.

GEOPHYSICS

The Geophysics Division makes geophysical surveys as an aid to the understanding of the geology of Canada and carries out research on the development of new instruments and methods in, among other fields, electromagnetic, resistivity and magnetotelluric surveys; magnetic methods; rock magnetism; seismic methods; and remote sensing.

Field activities of the Division during the period covered by this report included (1) telluric and magnetotelluric studies in Manitoba, Ontario, Quebec, and New Brunswick; (2) evaluation of in-situ susceptibility meter and related studies at Bancroft, Ontario; (3) collection of samples for palaeomagnetic study in Yukon Territory and District of Mackenzie; (4) seismic studies in British Columbia and Saskatchewan; (5) research into the use of seismic waves in the study of groundwater problems in southeast Saskatchewan and Manitoba; (6) a feasibility study for using seismic techniques to determine the thickness of strata overlying uranium pay-zones, Elliot Lake, Ontario; (7) determination of thickness and attitude of sediments overlying basement rocks in various parts of coastal Newfoundland and Nova Scotia; (8) a broad reconnaissance in the Elliot Lake area, Ontario, for radioactive minerals using the ground gamma-ray spectrometer; and (9) as assessment of the geological potential of coloured air photographs, using a geologically known area--Carleton Place, Ontario.

Members of the Division continued to participate in the management of the federal-provincial aeromagnetic survey program. Three 3-year contracts were drawn up and let for certain areas in Quebec, Saskatchewan and British Columbia. There are now nine different areas under contract for aeromagnetic surveys in various provinces and territories in the country. Geophysics personnel checked 411 one-mile aeromagnetic map compilations and 36 four-mile composite maps resulting from the program.

In the laboratories staff geophysicists undertook the development and/or construction of several types of electronic equipment, including a lightweight magnetometer suitable for installation in a light twin-engined aircraft and a field susceptibility meter. In the palaeomagnetic laboratory, work included the measurement and testing of the palaeomagnetism of dykes from Val d'Or-Noranda, Sudbury, and southern Nova Scotia. A study of the palaeomagnetism of the Manicouagan area was completed and an investigation on the magnetic properties of sulphides is in progress.

PETROLOGICAL SCIENCES

The Petrological Sciences Division is responsible for research, development and services in the fields of isotope geology, analytical

chemistry, mineralogy, petrology, and data processing to complement and support the work of the Geological Survey.

The Division measures the age of rocks, minerals and carbonaceous materials, using methods based on the radioactive decay of naturally occurring nuclides. It also investigates stable isotopic variations in nature and conducts fundamental research using enriched stable and radioactive isotopes in laboratory and field studies, a research designed to yield information regarding the magnitude of isotopic fractionation to be expected in biochemical and geological environments.

The age-determination program was continued, and 186 K/Ar age determinations, 13 Rb/Sr isochron studies, and 265 radiocarbon age determinations were made. The first two techniques are used to date rocks and minerals, usually of great age, and the resultant dates are used to unravel tectonic history and to identify periods of intrusion and metamorphism in the Appalachian, Precambrian Shield, Innuitian and Cordilleran regions. Radiocarbon methods give reliable dates only if the material tested is less than 54,000 years old. Most radiocarbon samples processed by the Division were selected to provide data for current research in Quaternary chronology, to shed light on crustal movements as evidenced by shore-level changes, and to provide information on the rates of geological processes, such as sedimentation. Some archeological material is being dated, and one sample of wood from a carved figure of historical interest was dated for the National Gallery of Canada.

During the period covered by this report the major emphasis in isotope geology has been on the refinement of Rb/Sr age-determination techniques. The Geological Survey has recently assumed responsibility for the development of a national system of recording for all Canadian isotopic age data as a service to the public, to earth scientists, and to the mineral industry. The format to be used has been developed and distributed to interested laboratory workers for discussion.

Stable-isotope studies continued on a reduced scale owing to the heavy requirements of the age-determination program; 136 sulphur-isotope determinations were made for staff members.

Chemical and instrumental analyses of rocks, minerals and related terrestrial and extraterrestrial materials were continued in order to meet the demand for more varied and sensitive analytical data. A total of 69,836 individual determinations were made. The number of samples submitted for rapid analysis was about 400 more than that submitted the previous year, but there was a considerable decrease in the total number of samples submitted for spectrographic analysis. The backlog carried in the fiscal year 1967-68 is much smaller than that carried in 1966. Research development included the development of a non-fusion general method for silicate rocks, studies directed toward a reliable determination of fluorine in silicates, the development of a new spectrophotometric method for the determination of palladium, and an evaluation of a titrimetric method for the determination of silica as a possible alternative method for routine use.

Mineralogical studies made by the Division cover the physical and chemical properties of minerals using X-ray, electron-beam and other techniques. The Survey's mineralogists provide mineralogical data to staff geologists for use in solving geologic problems, compile and publish data on Canadian mineral localities, catalogue the National Mineral Collection, collect bulk rock and mineral samples in order to assemble collections for public sale, and identify rock and mineral samples as a public service.

The number of mineral and rock collections distributed was 8,218, and staff members prepared two tons of rock chips for construction of a mosaic map of Canada for display at Expo '67. More than 1,600 samples of rocks and minerals were examined for members of the public, and the reorganization of the systematic Reference Series to Dana's new system was completed.

Petrological studies carried out by the Division are designed to investigate the theories and problems of petrology and to elucidate petrologic problems of economic or regional significance encountered by other Survey geologists. A major study of granites in Canada continued. At present it is directed toward the elucidation of problems of plutonism and migmatization in a well-defined mountain belt in southern British Columbia. As part of a study of ultramafic rocks in Canada the petrologic study of the Muskox Intrusion in the Northwest Territories was continued. Laboratory investigation of Canadian meteorites was continued by members of the staff as were studies in the fields of data processing and geomathematical research.

ECONOMIC GEOLOGY

The studies carried out by this Division are directed primarily to those aspects of geology that have a direct commercial application, i.e. the study of mineral deposits, geochemistry, engineering geology and Pleistocene geology. Since the last annual report was prepared the Groundwater Section, with the exception of the Engineering Geology Unit, was transferred to the Water Research Branch.

The most significant accomplishment of the year in the geology of mineral deposits was the first publication applying concepts of genesis of uranium deposits to our knowledge of the geology of Canada and so providing a direct assessment of those areas in Canada where the more important types of uranium deposits should be sought.

Five field projects were directed towards the study of mineral deposits, three examined nickel, iron and tin deposits throughout Canada, two others concentrated their efforts in the District of Mackenzie and the Sault Ste. Marie-Chibougamau regions studying many different types of deposits and attempting to relate them to the overall geology.

The evaluation of dam sites in Yukon Territory and a geological assessment of the new routes of the Welland Canal System were carried out by the Engineering Geology Unit.

Studies concerned with the development and testing of methods that can be used to delineate anomalously high concentrations of metals on both reconnaissance and detailed scales were carried out as part of the geochemical research program. The immediate acceptance by industry of methods devised for locating silver-bearing veins in the Cobalt area of Ontario and the staking rush that followed release of geochemical surveys in the Bathurst area, New Brunswick, are evidence of the success of this program.

Pleistocene geology is concerned with the study of unconsolidated deposits, mainly of glacial origin, which cover large parts of the country and on which most of Canada's cities are built and her crops and forests grow. The work carried out by the Geological Survey comprises areal studies and topical projects designed to solve specific problems. The results of the areal studies are used extensively by agencies concerned with forestry, agriculture, land inventory, groundwater and engineering. Several projects were undertaken to meet the specific requirements of one or more of these agencies.

Eighteen projects were carried out during the 1966 field season. The surficial geology of parts of southern Yukon Territory and the Mackenzie Delta region was studied. The valleys of the Peace, Findlay and Parsnip Rivers in British Columbia were examined in advance of hydro-electric development and a similar study was carried out in the Columbia and Kootenay Valleys. Palynological studies were made on the Prairies. Areal studies were made in Iosegun map-area, Alberta; Gananoque, Ontario; Stratford-Conestogo, Ontario; southeastern Quebec and Summerside, Prince Edward Island. The uplift of the Hudson Bay and Lake Huron Basins was studied and the surficial deposits of the Kirkland Lake region were examined as part of a program designed to assist in mineral exploration.

REGIONAL GEOLOGY

The Regional Geology Division has as its prime objective the systematic investigation of orogenically disturbed regions, such studies being directed towards the recognition of fundamental geological models, known or new, and their implications in regard to mineral explorations. Studies are carried out in three of the four orogenically disturbed regions of Canada -- the Cordilleran Region on the west, the extensive Precambrian Shield of central and northern Canada, and the Appalachian Region of the east.

Eleven field parties carried out studies in the Cordilleran Region; seventeen on the Canadian Shield; and six in the Appalachian Region.

In the Cordilleran Region activities were mainly directed toward completion of the reconnaissance phase of regional investigations, although other more detailed and more specialized projects such as volcanological, structural, stratigraphic and metamorphic studies were also conducted. One party completed the reconnaissance of Sekwi Mountain, Nahanni, Frances Lake, Watson Lake and Jennings River map-areas, in Yukon Territory, District of Mackenzie and northern British Columbia. A reconnaissance study of about half of McBride map-area, British Columbia, was completed. Other investigations in British Columbia concerned central Vancouver Island, the metamorphic terrain along Canoe River valley, a program of volcanological work in association with the Observatories Branch in the vicinity of Mount Edziza, the Atlin Horst in the northern part of the province and the Mesozoic stratigraphy of the Skeena River region. Three graduate students undertook theses projects as part of the Cordilleran Structural Project, and one graduate continued a structual and petrographic study of the Grand Forks Group rocks.

Although no major helicopter-supported reconnaissance projects were carried out on the Canadian Shield, aircraft were used extensively by most of the 17 field parties, both for transportation and as traversing tools. One helicopter was shared by several parties in the Western Shield and was moved north and south to take advantage of changing ice and weather conditions. Most projects involved areas and problems of significance to geological theory and/or of importance in mineral exploration in northern Canada. One party continued the study of the structure and petrology of gneisses south of the East Arm of Great Slave Lake, and a graduate student began a thesis project on the stratigraphy, sedimentology and tectonics of the Proterozoic rocks in the same general area. As part of a broad study of volcanic piles in the Canadian Shield one geologist studied the volcanic rocks of the Coppermine River Group. The reconnaissance study of the gold-bearing Point Lake-Contwoyto Lake area was completed, as was the mapping of Wholdaia Lake map-area and a study of the internal constitution of the Dubawnt Group. A study of a critical strip across the northern end of the Ennadai-Rankin orogenic belt was started. Ten field parties carried out studies in that part of the Shield lying east of the Manitoba-Ontario boundary.

The field phase of a study on the age, petrology and tectonic importance of the diabase dyke swarms of the Shield was completed. A graduate student completed the field work on his thesis study in the Hastings area of Ontario, another student commenced a structural and metamorphic petrological study of the Naskaupi and older fold belts in Labrador and a third student began a study designed to define the volcanic-sedimentary stratigraphy of the Kirkland Lake area and to relate this to the known mineral occurrences. The latter project was directed by a staff member who also started a study of Archaean volcanic belts. A study of the Grenville metamorphic front north of Lake Huron was continued, as was a detailed study of the sedimentary sequences in the volcanic-sedimentary belt between Sioux Lookout and Savant Lake, northwestern Ontario. A geological reconnaissance was made of the Northwest River area of Labrador, and preliminary studies were carried out in connection with Operation Torngat, planned to begin in 1967.

In the Appalachian Region six projects were carried out in central New Brunswick, a detailed study of the stratigraphy and structure of the Ordovician and Silurian strata was begun in the McKendrick Lake area. In southern New Brunswick a detailed study of the stratigraphy, structure, and mineral deposits of the St. Stephen-Pleasant Mountain area was completed, an area containing tin, molybdenum and nickel deposits. In northern Nova Scotia, detailed studies of Lower Palaeozoic rocks continued in the Cobequid Mountains and were completed with re-examination of key areas in the Antigonish Highlands. Regional investigations of Ordovician and Silurian volcanic and sedimentary rocks in Red Indian Lake area, central Newfoundland, which includes the Buchans lead-zinc-copper mine, was completed and work in Burgeo area to the south was begun. The results of recent studies by mining-company and university geologists on the Burlington Peninsula, northern Newfoundland, were investigated and a detailed structural analysis of a key part of the area was begun by a post-doctoral fellow. The study of the Lower Palaeozoic klippe rocks at the north end of Great Northern Peninsula was continued.

FUELS AND STRATIGRAPHY

This Division is concerned primarily with the unmetamorphosed, stratified, largely marine fossiliferous rocks, in which oil, natural gas and coal--the fossil fuels--are most commonly found. Thus the principal objective of the Division is to determine the succession, lithology, structure, age and correlation of the sedimentary bedrock formations in Canada; to chart and otherwise illustrate the surface and subsurface distribution of these rocks in space and time; to carry on research in structural geology, stratigraphy, sedimentology, palaeontology, and to study the petrologic and organic constitution of coal seams. A permanent repository for well cores and cuttings is maintained, and these materials are made available to visiting geologists for study.

Nine field parties carried out stratigraphic investigations in Canada's sedimentary basins. A reconnaissance investigation by several staff members of the regional geology of about 12,000 square miles of the southern Rocky Mountains was completed, as was the mapping of the Palaeozoic rocks of southern Ontario. Tectonic and structural studies were carried out in various parts of the Foothills area, and mapping of areas of the southern Alberta Plains was continued.

On the Arctic Islands, Operation Grant Land, begun in 1965, was completed. This project involved four staff members and included studies in stratigraphy and structural geology.

The investigation of the various forms assumed by living animals in the past is of great importance as fossils form an important criterion for determining the regional and intercontinental equivalence of stratified rocks. To further this aim, palaeontologists of the Division prepared 203 reports on 3,008 lots of fossils. Loans and exchanges of material were made to individuals and institutions in Canada and elsewhere. In Canada and five other countries, 52 experts on particular groups of fossils are engaged in studies on Geological Survey material that result in reports to field officers and/or publications on Canadian fossils. Forty-five geologists from universities, oil companies and abroad made use of the Survey's fossil collections or consulted with staff members during the period covered by this report.

Investigations of Canadian coals and associated clastic sediments were continued. Petrological studies were carried out to obtain information valuable for coal geology, coal mining and coal utilization, particularly as applied to research on coking coals. Palynological (spore) investigations designed to assist in determining the stratigraphy of the coalfields and regions with Permian and Carboniferous rock were continued.

A field and laboratory study was made of the Pictou coalfield at the request of the Nova Scotia Department of Mines. The uranium possibilities in the Saskatchewan lignite exposures were investigated and visits were made to North and South Dakota where commercial quantities of uranium ore are extracted from lignite.

The Mines Branch is a complex of laboratories and pilot plants designed to assist the Canadian mineral industry in the more efficient extraction and elaboration of mineral wealth of all types, and to improve and broaden the uses of metals and minerals. During the fifteen-month period under review the Branch continued a number of promising research projects and started several new ones.

The work is carried on in six divisions -- Physical Metallurgy, Fuels and Mining Practice, Mineral Sciences, Extraction Metallurgy, Mineral Processing, and Mining Research.

Physical metallurgy is concerned with the composition and behaviour of pure and alloyed metals as well as the smelting of iron and steel. Much of the work falls into the category of "trouble-shooting" for government departments and private industry. The degassing of molten iron and steel, and methods for measuring oxygen content of molten steel are samples of its foundry research. Research on fuels concerns especially the refining of heavy, low-grade crude oils and better uses of Canadian coals. In mining safety, attention is directed to such problems as the operation of electrical equipment in explosive atmospheres.

Mineral-sciences experts study the composition and properties of useful minerals. The complicated sulphides occupy much attention, as do multi-oxide systems of such elements as niobium, tantalum, iron, aluminum and manganese. Research is also being conducted on the fabrication of piezoelectric and magnetic ceramics and the elaboration of mineral standards. Extraction metallurgy is concerned with hydrometallurgical and pyrometallurgical methods for processing ores. Also studied are the causes and cures of corrosion, hydrogen embrittlement of metals during electroplating, and analytic procedures. Research in mineral processing covers the flotation, jigging, and filtration of metallic minerals, the processing of industrial minerals such as clays and shales, preparation of concrete, building stone, asbestos, and other materials. In the mining-research laboratories, rock mechanics, drilling and blasting, the application of computers to mining operations, and the testing of explosives under the Canadian Explosives Act occupy most of the work.

Details of these and other investigations will be found in the following.

PHYSICAL METALLURGY DIVISION

The work of the Division in support of Canada's metal and mining industries encompassed both fundamental and applied research as well as short-term investigations to resolve problems of immediate urgency. The Division continued to meet requests from industry and from other government departments for consultation and advice on metallurgical problems, especially the Departments of National Defence, Transport, Agriculture and Public Works, as well as such agencies as the National Energy Board, National Research Council, Atomic Energy of Canada and Eldorado. Industrial concerns ranging from primary metal producers through manufacturers and consumers down to small foundries and shops are represented among those calling upon the assistance of the Division.

In the international field, senior staff members participated in numerous organizations, particularly in support of Canada's defence commitments at home and abroad, as well as the development of international standards and specifications. Visits to the laboratories by distinguished scientists from abroad attest to the interest in work being done and permit discussions on new developments within the Division and elsewhere.

Investigations of damaged or otherwise unsatisfactory metal components continued to be an important part of the Division's service. This work, primarily directed to determination of the cause of each problem, generally leads to recommendations for prevention or remedy where possible. During the period covered, such metallurgical investigations and assistance covered military equipment, aircraft components, ship's propellers, gas-transmission pipe, steel rails for heavy-duty iron-ore traffic, mining equipment and miscellaneous industrial metal products. Components of crashed or damaged aircraft necessitated thorough metallurgical investigation to determine whether they contributed to the accident. Many foundries encounter problems with castings associated with moulding sands, and an important service is rendered by testing and examining such sand, with appropriate recommendations. The failure of heavily stressed parts due to fatigue requires expert analysis of the mechanical and metallurgical factors involved.

Among the more unusual and interesting items investigated were an ancient ship's anchor recovered from the bed of the St. Lawrence, which was confirmed metallurgically to be of puddled iron characteristic of the 1600-1840 period, and a survey marker dating back to 1882 which had suffered abuse. With short supply of silver and prospects for a higher price, its displacement in the common coinage of the country is expected soon, and assistance was rendered to the Royal Canadian Mint to develop nickel coins that would not run afoul of vending-machine slug-rejector mechanisms. Assistance was given to the Canadian Wildlife Service in a search for non-toxic bird shot to prevent lead poisoning among water fowl swallowing the pellets.

Advice was given to a manufacturer of safes on incorporating cast-in-place refractory materials, and a company was assisted in a metallurgical problem concerning a lead-tin alloy for producing organ pipes.

An important function of the Division is the certification of industrial radiographers on behalf of the Canadian Government Specifications Board. This activity has grown considerably in recent years, and in the period covered, 29 senior radiographers and 84 junior radiographers received certification. The number of candidates may be expected to increase, since certification of radiographers is required by the R.C.A.F. for aircraft materials and the Atomic Energy Control Board has specified that only certified personnel may conduct radiography using radioisotopes.

Research, for which the laboratories of the Division are both well equipped and staffed, embraced a wide range of important work in ferrous and non-ferrous metals. The importance of iron and steel in the economy of the country is recognized by a large proportionate effort with these metals. Extensive research is being conducted on new melting and refining processes. In particular, degassing methods, mechanisms of solidification and alloy development are being studied.

A method for directly measuring oxygen content of molten steel is under development. Its attractions are expedience and economy, both important for better production control and quality of product. The wider use of ultra-strong steels, which is desirable to improve performance through better strength/weight ratio, has required extensive study of those sudden catastrophic failures amenable to metallurgical control. This work is particularly relevant to the development of hydrofoils and advanced aircraft components.

In its search for new and better ways of using non-ferrous metals, the Division experimented with a new use for gold in preventing hydrogen embrittlement of highly stressed steel components. Similarly, work on improvements in zinc-galvanized coatings is directed to increased use of zinc and better protection for composite assemblies made from several different steels. Work has been conducted for many years on development of new high-strength magnesium-zirconium alloys, and this has now been extended with promising results to similar alloys containing silver.

Dispersion strengthening of zirconium by the direct addition of

refractory compounds during inert-atmosphere arc melting is under investigation, with intriguing early results, and a study has been initiated on the possibility of fibre-reinforcement or dispersion-strengthening of magnesium by magnesium oxide. Division personnel are also working on a process for producing better bismuth-telluride thermoelectric material. This would expand the use of this type of material in solid-state electronics, such as refrigeration devices having no moving parts.

In addition to the more obviously practical aspects of physical-metallurgy research described above, a considerable effort is being made in metal physics. This work is directed to the elucidation of phenomena of the metal state, particularly the atomic arrangement and structure of metals and alloys. The mechanisms of creep and cohesive failure and the manifestation of fatigue damage are important topics of study, as are those of solidification and diffusion. Continued ion bombardment of metal crystal surfaces has provided further confirmation of this technique for the rapid and convenient determination of crystallographic orientation. The work is being extended to studies of metal crystals and their behaviour in corrosion resistance and catalysis.

FUELS AND MINING PRACTICE DIVISION

The conversion of Canada's mineral fuel resources into products that will meet the diverse needs of modern industry is one of the major roles of the Fuels and Mining Practice Division. Consequently, this Division is deeply concerned with all the numerous aspects of chemical process engineering required to transform coal, as well as low-grade petroleum and natural bitumen, into products acceptable to industry.

The approach adopted by the division for the refining of residual oil and bitumen was to select the most direct route for the conversion of these substances into jet fuel with a minimum of waste. For this purpose a combined liquid-and-vapour-phase pilot plant was constructed and operated during the year. The result of operating this pilot plant has shown that a suitable catalyst can be made in Western Canada for the large-scale industrial refining of this class of oil, and further, that this catalyst has an activity which is equal to that of the standard catalyst used for this process in Europe.

The difficulties of operating the pilot plant in a stable manner have been overcome, and it is expected that a steady improvement will be made during the current year.

The catalytic-cracking program which involves the construction of a fluid-bed pilot-plant unit capable of operating at pressures up to 1,000 pounds per square inch was continued. The feed system has been put into operation, and the catalyst recirculation will be tested shortly. When completed, this pilot plant will be used to refine the intermediate products from the hydrogenation program of this division.

Catalysis plays an extremely important role in the refining of low-grade crude oils. The search for improved catalysts was continued during the year using the automated testing facilities previously constructed. The results to date suggest the importance of diluting the bitumen with a middle oil of good hydrogen transfer characteristics, and of sufficiently high boiling point to avoid the formation of hydrocarbon gases.

As concerns mineral-matter removal from heavy oils, it was shown that hydrocracking in the absence of a catalyst or diluent was an advantageous preliminary step. It remains to be shown that it is more economical than a pure visbreaking operation. However, it is already evident that hydrocracking has great merit from the point of view of conservation, and consequently further research in this area is proposed.

During the past year some new trends have developed. The combustion section of this centre has been separately designated as the Canadian Combustion Research Laboratory. The research of the laboratory formerly concerned the combustion of Canadian coals and particularly such questions as the fouling of superheater tubes when burning the Venezuelan crude oils. By contrast, the the emphasis during the past year has been on developing methods of reducing atmospheric pollution at the combustion source. The progress has been most encouraging. A magnesia-alumina additive to fuel oil has been developed that is very helpful in the elimination of acid-smut pollution. This additive is already gaining rapid industrial acceptance in the United States.

One of the most important problems of the maritime coal industry relates to the reduction of the sulphur content of the coal so that it may hold its market in the local steel industry as a source of coke. It is well known that half of the sulphur content of coking coal is associated with the mineral pyrite. However, due to particle-size limitations for the conventional coking process, little effort has been made to remove the pyrite by new means available in conventional coal-cleaning plants. Because of the great difficulties confronting the Cape Breton coal industry, studies were undertaken, with the support of the Dominion Coal Board, to determine the maximum elimination of sulphur that may be achieved by physical separation with different sizes of coal lumps. It has been shown that the size reduction need not be too extensive to arrive at sulphur levels acceptable to the steel industry, and, in addition, it was demonstrated that low sulphur contents of about 0.6% could be achieved by fine grinding (-200 mesh). Research is now in progress to study the agglomeration and dewatering of fine coal to prepare agglomerates that will be acceptable for coke manufacture in conventional ovens.

The removal of the mineral matter from coal plays an extremely important role in holding the present markets for coal and in developing new markets in Japan. The same principles that apply to the beneficiation of coal also apply to the beneficiation of many of Canada's low-grade ores. Because of the importance of improving mineral separations to the whole Canadian mineral economy, the Western Regional Laboratory has concentrated on the design of cyclone separators for separating minerals and purifying water. Considerable progress was made during the year on the improvement of the materials of construction of the "Slugging Cyclone." Special emphasis has been placed on this program to enable closed-circuit operations to be introduced in coal-washing and mineral-dressing plants, thus preventing water pollution at the source.

The safety of personnel and property is of great concern in underground mining, and also in many industrial activities involving explosive or inflammable materials. The section of the Fuels and Mining Practice Division dealing with this aspect of public safety has recently been separately designated as the Canadian Explosive Atmospheres Laboratory. In addition to its research, this laboratory also checks on and certifies the safety of mining equipment. How this work has grown may be deduced from the eightfold increase in fees in the last ten-year period, and there is no sign that the trend is levelling off. It has been difficult to increase the staff at a rate sufficient to give adequate attention to research. Nevertheless, the Canadian Explosive Atmospheres Laboratory published a report on hydrogen explosions relating to electrical apparatus. This was presented in 1966 at the first international meeting to be held in Canada of an International Electrotechnical Commission Technical Committee. The report was used as a basis for discussing international recommendations for the construction of electrical apparatus for use in explosive atmospheres of hydrogen in air.

In recent years, more equipment has appeared which is not in special explosion-proof enclosures. This category includes instrumentation, control circuits, and communication systems. Often such equipment operates at low electrical-energy levels and may be certified as "Intrinsically Safe" if it cannot produce sparks capable of igniting explosive atmospheres. Considerable research has been conducted in the laboratory concerning the energy available and the energy which can be released from iron-cored inductance coils which are often used in communcation and remote-control circuits.

MINERAL SCIENCES

The research of the Division has been concerned with eight major programs.

The most extensive of these is the multi-disciplinary study of sulphide minerals. This study has given special emphasis to the many economically important sulphide minerals occurring in Canadian orebodies. The structures of sulphides and related minerals are being studied intensively in an effort to determine the reasons for the wide variations in composition and structure, to systematize the classification of sulphide minerals, and to develop a greater insight into the relationship between crystal structure and chemical and physical properties.

In order to provide basic data for the structural study, a laboratory has been equipped with the most up-to-date types of apparatus for X-ray diffraction, including an automated four-circle goniometer, controlled by an on-line digital computer.

Phase-equilibrium studies are being conducted in some of the more important sulphide systems. This is done by synthesizing sulphide minerals under carefully controlled conditions of temperature, vapour pressure and composition, and relating the resulting assemblages to the conditions of formation.

In addition, as part of the sulphide program, a crystal-growing project has been initiated, the objective of which is to prepare large single crystals of various sulphide minerals. A study of the growth of sphalerite (ZnS) using a chemical vapour transport method has been made, resulting in the growth of some crystals up to 5 millimetres long. Some exploratory work on the effects of the addition of foreign elements to the synthetic crystals has been carried out. The program will be extended to cover other methods of crystal growth.

The work on the phase-equilibrium study of multi-oxide systems of mineralogical and metallurgical significance that has long been one of the lines of major research effort in this Division continued throughout the year. In continuation of the series of studies involving niobium and tantalum pentoxide that has been made in recent years, studies of the systems $CaO-Nb_2O_5-TiO_2$ and $CaO-Ta_2O_5-SiO_2$ have been initiated and are leading to some interesting results. Studies of the Ti-O system, initiated several years ago but later discontinued due to pressure of other work, have been reinstated and brought to a successful termination. Studies in the complex refractory oxide systems $CaO-Al_2O_3-Fe_2O_3-SiO_2$ and $MgO-Al_2O_3-SiO_2$ have also been continued during the period under review.

Work has continued in the devising of new analytical methods and in the study of the physical and chemical properties of numerous complexes on which analytical procedures might be based. Using ligand or crystal field theory to interpret the absorption spectra of transition metal ions in solutions, in crystalline complexes and in certain minerals, it was found possible to gain information on the valence state of the metal ion and on the geometry and constitution of its co-ordination sphere. Several studies of this kind were conducted in the review period. The near-ultraviolet to near-infrared spectra of various copper, nickel and cobalt complexes, formed mainly in acetone solutions, have been correlated with their structures. Many of these complexes had not previously been isolated or their nature elucidated.

The absorption spectra of silicate minerals such as biotite, xanthophyllite, tourmaline, kyanite and cordierite have been studied, and valuable information on the oxidation state and siting of the various cations has been obtained. From such studies, it is often possible to explain certain optical properties of the minerals, such as colour and pleochroism.

The Division has participated on an increasing scale in standards work in collaboration with national and international standards organizations. The first testing and evaluation of methods for the determination of manganese, silica and phosphorus in iron ores and of chromium oxide in chrome ores was completed for the American Society for Testing and Materials (ASTM). Testing and evaluating methods for determining silica and fluorine in fluorspar, sulphur in iron ores and the manganese-dioxide content of manganese ores are in progress. The Division assisted in the standardization by the National Bureau of Standards of Sibley Iron Ore. Participation continued in the work of the Chemical Analysis Group of the Advisory Group for Aeronautical Research and Development (AGARD) of NATO. During the past year the copper, nickel and iron content of molybdenum metal was determined by wet chemical methods, and proposed polarographic techniques for traces of tin in tantalum metal were evaluated. Instrumental techniques such as the use of atomic absorption spectra for the determination of the lime and magnesia contents of iron ores are being investigated as part of the Canadian contribution to the International Standards Organization (ISO). In addition to these, the Division has assisted the Canadian Association for Applied Spectroscopy in the determination of trace elements in copper metal to be certified as spectrographic standard.

The Divisional program on the study of piezoelectric and magnetic ceramics, largely sponsored by the Defence Research Board and the Department of Industry, has been continued throughout the year with the further investigation of factors affecting the fabrication and sintering behaviour of such materials and of the effect of chemical changes on the electrical and magnetic properties of the resultant materials. In the study of the "hard" or permanent-magnet type of ferrites based upon lead/strontium/barium hexaferrite compositions, novel methods of preparation have been investigated. A press, designed to maintain a strong orienting magnetic field during the fabrication of the shapes, has been constructed and placed in operation. A phase study of the barium oxide/iron oxide and strontium oxide/iron oxide systems is under way to define the nature of the various possible compounds in these systems. A considerable amount of work has been done in conjunction with Canadian industry with a view to characterizing the oxides and assessing their suitability as potential raw materials for ferrite manufacture.

Investigations of Canadian ores, with particular reference to those mineralogical characteristics that affect recovery and beneficiation, are being undertaken. The most comprehensive of these involves a study of the silver-cobalt deposits of the Cobalt-Gowganda district of Ontario.

A program on the surface properties of minerals, particularly as they relate to their flotation behaviour, is under way. The measurement of the surface area of oxide minerals by the Kr. adsorption method is used. Studies of the solid-liquid interface behaviour of oxide minerals in various solutions have been made; a contact-angle apparatus has been constructed to study the hydrophobicity of mineral surfaces when treated with surface-active agents. An extended series of studies of the flotation of hematite in oleic-acid solutions and the interpretation of the behaviour in terms of surface structure is under way.

In a program designed to investigate the semi-conductor properties of minerals and related measurements, a study has been made of the temperature dependence of the ion drift of silver in single-crystal bismuth telluride at various current densities.

In addition to the above-mentioned research projects the Division conducts a large number of service investigations employing a variety of techniques such as wet chemical and instrumental analyses, X-ray and emission spectroscopy, X-ray diffraction, differential thermal and thermogravimetric analyses and neutron diffraction. Most recently, Mossbauer spectroscopy, also controlled by the "on-line" computer, has been added to the facilities available in the Division. These service investigations are conducted on behalf of other divisions of the Mines Branch, other government departments such as the Deparment of National Defence, the Department of Transport, the Canadian Government Printing Bureau, the Royal Canadian Mint and the R. C. M. P.; some work of assistance to industry and universities is also conducted.

EXTRACTION METALLURGY

In extraction metallurgy, applied research continued on the development of hydrometallurgical and pyrometallurgical processes, on electroplating technology, and on causes and prevention of metal corrosion. At the same time, fundamental studies were carried out on the kinetics and thermodynamics of metallurgically important chemical reactions. Liaison with the uranium-mining and the gold-mining industries continued through the activities of the Canadian Uranium Producers' Committee and the Association of the Canadian Gold Metallurgists.

Hydrometallurgical research concerned the treatment of uranium, gold, and base-metal ores. The leaching of uranium from Elliot Lake ores by bacterially produced acidic-ferric-sulphate solutions was investigated, both to test its applicability to the salvaging of residual uranium from mine and concentrator wastes, and also to examine its possibilities as a primary leaching process to supplant the conventional hot-acid leaching now in use.

Studies of improving hydrometallurgical processes by mathematical simulation techniques were undertaken. A laboratory investigation was made to determine the effects of temperature and acid on the extraction of uranium from an Elliot Lake ore, under conditions suitable for statistical analysis. From this investigation a second-order equation was developed which related the variables of temperature and of acid addition to uranium extraction, and which ultimately may be used to assess, by calculation, the efficiency of various possible leaching conditions. Similar mathematical simulation programs are being carried out on grinding circuits, continuing from an earlier investigation on the application of automatic control to grinding circuits. A laboratory study is also being made to determine the mathematical relationships in the cyanide process between process variables and gold extraction.

A process for the production of high-purity tungstic trioxide from a Canadian scheelite ore was brought to small-scale pilot-plant operation during the year. Tungsten recoveries were excellent and reagent consumptions were modest, and it appears that the process will be attractive economically not only in Canada but probably elsewhere.

The development of a hydrometallurgical process for the production of mixed oxides of controlled chemical composition and physical properties for the manufacture of lead-zirconium-titanium oxide ceramics was largely completed by the end of 1966. The most recent innovation was the introduction of fatty-acid flotation to separate the mixed lead-zirconium-titanium oxide precipitate from the wash solutions.

In an investigation into the causes and prevention of metal corrosion in industrial environments, samples of mild steel, high-strength steels, stainless steels, copper and zinc were exposed to sulphurous, hydrochloric, sulphuric and nitric acids. Not all these metals were attacked by sulphurous acid, but where sulphurous acid attack did take place, it proved to be very rapid in comparison with the attack by the other acids. It was also found that the rates of corrosion by all these acids could be expressed as mathematical functions of the normalities of the acids in contact with the metal.

In view of the seriousness of the corrosive effect of sulphurous acid on some metals particularly steels, inhibitors against its attack have been sought, and it has been found that ammonium oxalate and hexamine are particularly effective.

The study of the prevention of hydrogen embrittlement in high-strength steels during pickling and electroplating was continued. It was found that hydrogen embrittlement during pickling could be greatly reduced if an oxidizing agent such as ferric sulphate or nitric acid was incorporated in the pickling solution, or if the metal being pickled was made anodic during pickling. A potential of no more than 0.5 volt was found to be adequate.

Work on the prevention of hydrogen embrittlement during electroplating also continued. The earlier investigations on electroplating of zinc and cadmium were extended to include copper, which can now be plated onto a number of high-strength steels without producing embrittlement. Similar attempts with chromium have not been successful. It was found, however, that if high-strength steels were first plated with copper, chromium could then be electroplated over the copper, to produce a good chromium-plated surface without embrittlement in the basis metal.

In pyrometallurgy the development of the combined shaft furnace-electric furnace unit continued. This unit is designed to make possible the application of oil, natural gas, or electric power to the smelting process, so that the most economical combination can be used for any particular purpose or location. Improvements to the shaft furnace were made to ensure that better use was made of the off-gases from the electric smelting to preheat the incoming feed to the furnace. In a pilot run making high-carbon iron from metallized iron pellets, an energy input of 840 KwH per net ton of pellets were achieved, of which 700 KwH was supplied as electrical energy and the balance as thermal energy. Projections based on theoretical maximum throughput of the shaft furnace-electric furnace unit indicated an ultimate energy requirement of 725 KwH per ton, half of which could be supplied as thermal energy in the shaft. Similar data were developed for the smelting of ilmenite ore to produce metallic iron and high-titanium slag.

The data for these preliminary pilot-plant runs have been used to design an improved version of the shaft furnace-electric furnace combination which will yield energy-consumption data for a variety of smelting operations. The design permits the furnace to be automated to a large degree, if this should prove desirable. This aspect of the project is being conducted in co-operation with the National Research Council.

Other pyrometallurgical research included investigation of the factors controlling the pelletizing of ores, such as the effects of individual ranges of feed-particle size on the unfired-pellet strength. In another program, sintering studies were carried out on minus-twenty-mesh chrome fines with the object of converting this product to usable material for the manufacture of certain refractories.

Basic research on chemical reactions of metallurgical importance included a study of the kinetics of the dissolution of the copper mineral covellite in acidic-ferric-sulphate solutions. This reaction, and similar reactions with other minerals, is of importance in the heap-leaching of copper ores, and of potential importance in the leaching of uranium ores by solutions of ferric sulphate generated by bacterial action.

Completed during the year was a thermodynamic study of the principal reactions resulting from the treatment of a complex sulphide concentrate containing iron, nickel, copper and cobalt with chlorine to produce sulphur in elemental form, iron in the ferric oxide form, and nickel, copper and cobalt as chlorides. The study indicated that a reaction temperature of about 400°C would be suitable, since at this temperature all the principal reactions would go in favourable directions to produce solid nickel, copper and cobalt chlorides and a mixed gas containing ferric chloride and sulphur. Appropriate conditions for separating ferric chloride from sulphur, and for converting ferric chloride to ferrous chloride were established, and finally the conditions necessary for the conversion of ferrous chloride to ferric oxide, with regeneration of chlorine, were defined. The growing demand for sulphur in elemental form, and the growing need to reduce the pollution of the atmosphere with sulphur dioxide, the product of conventional methods of sulphide-concentrate treatment, emphasize the potential importance of this study.

In the development and modification of analytical procedures, the X-ray fluorescence technique was improved by adoption of a computer program developed to cope with the matrix effects encountered in the analysis of certain complex compounds. In addition,

an investigation was initiated of using the relatively new technique of atomic absorption for the control of industrial leaching. A simple method was developed for determining very low levels of free and complex cyanides that will help the gold-milling industry to avoid the pollution of rivers and lakes by cyanides contained in cyanide mill effluents.

MINERAL PROCESSING

The Mineral Processing Division carries out basic and applied research in aid of the mining, ceramics or construction-materials industries.

Flotation, jigging (gravity-concentration) and filtration investigations were carried out within metallic-minerals research to improve processes for industrial use. The role of depressants in iron-ore flotation and the electrochemical properties of mineral surfaces were studied to provide essential understanding of the flotation process. A research project on jigging was extended to titanium and asbestos ores. New methods of evaluating filter performance were devised, and the publication of this work has attracted international interest.

Pilot-plant investigations were made on seven shipments including iron, chromite, silver, titanium, niobium and copper-nickel. Approximately 300 tons of niobium (pyrochlore) ore was treated in search of a better method of concentration than that now in use in Quebec.

Seventeen investigations were undertaken on samples of ferrous and associated metals, including iron ores from the Yukon Territory and Pakistan. There was a noticeable increase in titanium and tantalum projects. Twenty-eight investigations for the non-ferrous industry included a co-operative project with the silver industry to decrease the costs of silver refining in the area of Cobalt, Ontario, a research project to find a process for treatment of talcose molybdenum ore in Quebec, and projects to recover gold from the tailings of the Kirkland Lake area mines.

The industrial-minerals research covers processing of a wide variety of non-metallic minerals and rocks submitted by individuals and companies, new or improved methods of products, and the provision of information on processing methods and uses, markets and specifications of minerals and products.

The research on the development of piezoelectric ceramics was concerned mainly with the effects of variations in preparation and composition on the properties of lead zirconate-titanite. The study of the heat capacity of a wide variety of minerals and ceramic bodies was concluded. Projects on thermal conductivity, on the properties of clays and shales, and on methods of pressing and firing ceramic clay continued. Methods of processing magnesite and pyrophyllite to produce suitable refractory products were studied. Samples of clay from British Columbia to New Brunswick were evaluated.

The increasing demand for better construction materials has resulted in stricter specifications and the need for better methods of production and evaluation. Methods for improving the manufacture of lightweight aggregate and the evaluation of concrete were under investigation. The method developed for accelerating the curing of concrete specimens has been accepted by the ASTM for a test program. Further work was carried out on the ring-test method for measuring the tensile strength of concrete. The division continued to provide the Canadian Standards Association with an impartial service for its co-operative cement-testing program, and will collaborate in its cement-strength survey. It supplied technical advice to various hydro-electric power organizations on the quality of materials.

Close contact was maintained with suppliers or possible suppliers of dimension stone in an effort to encourage greater use of Canadian stone. Assistance was given to Expo '67 in procuring rocks for use in the Geological Court in the Canadian Pavilion.

In the industrial-minerals mill, research projects on the floatability of pure minerals, the recovery of weakly magnetic minerals and electronic sorting were continued. Further work was done on the processing of fluorite. Studies were carried out on the use of ultrasonics vibration grinding, and vibration-materials-handling equipment. Smaller investigations were carried out on samples of industrial minerals submitted by industry from a number of sources.

The asbestos-research project dealt mainly with the study of particle size, surface area and dielectric properties of fibre. A static method for measuring the length and diameter of fibre has been devised, and equipment has been assembled. The use of zeta potential measurement in the measurement of surface properties is under study. A suitable method of processing by-product synthetic gypsum is being sought. Samples of various industrial minerals from many sources have been evaluated to some degree, generally to provide specific information to the supplier.

Almost all studies carried out in the division require prior mineralogical evaluation. Investigations of the relationship between the mineralogy and ceramic properties of clays and shales and between the mineralogy and physical properties of aggregates and building stones are carried out continuously. A study of the making of polished sections resulted in a method for producing inexpensive high-quality sections that could be used in remote locations.

MINING RESEARCH LABORATORIES

On advice from the Canadian Advisory Committee on Rock Mechanics, the Mines Branch has been able to stimulate mining research in the universities through its grants-in-aid which, starting with $10,000 in 1962, have grown to a total of $250,000 for the six years. In addition, the Committee, which consists primarily of representatives of industry and of the universities, has been able to co-ordinate research in rock mechanics throughout the country and to improve communication between interested parties. During its brief period of existence both the production of graduate students by the mining departments at universities and the volume of research throughout the country in rock mechanics have greatly expanded.

While experimental work continues in the laboratory and in the field, greater use is being made of applied mathematics through computers to expand analytical and predictive capabilities. This approach has shown that the mathematics on which the programs are based are very similar to the mathematics that would simulate other systems such as mine ventilation, heat flow, mining costs taking into account interaction of variables, and specialized subjects like the design of hydraulic fill systems. Consequently, wider application of the research will be possible.

The Canadian mineral industry is currently excavating about 400 million tons of rock per year at a cost of more than $1 billion. With the third-largest mining industry (excluding fuel) in the world, we have more rock problems and more requirements for rock research than most other countries. The major research is being conducted on problems where the potential payoff is estimated to be far in excess of the required costs.

The mines with which co-operative projects are being conducted produce commodities varying from salt and potash through coal and asbestos to base metals, gold and uranium, from British Columbia to Newfoundland. These studies are aimed at improving the design and operating methods of both underground and open-pit mining. As an example, one project concerned with improving the stability of deep open-pit excavations indicates a ratio of capitalized benefit/cost of more than 100 to 1.

The current cost of drilling and blasting in industry is around $100 million per year. The blasting research in process is aimed at savings in these operations that will produce a benefit/cost ratio of approximately 20 to 1. In addition, as a result of a survey made by the Mining Association of Canada some two years ago, a new program of research has been started on the fundamentals of non-explosive rock breakage, which may lead to some novel methods of mining.

A modest amount of work is being done on mine environments through the study of the techniques of dust measurements. This work is being done in co-operation with the Quebec Metal Mines Accident Prevention Association and the Mine Accident Prevention Association of Ontario.

Besides being part of the working team on the above-mentioned blasting research, this laboratory under the Canadian Explosives Act during 1966 tested 11 new explosives, 17 types of ammunition, 128 new kinds of fireworks, and checked previously authorized explosives and blasting accessories. Similar work was done for the Post Office Department and the Board of Transport Commissioners. As Canadian representative on the Group of Experts on Unstable Substances of the OECD (Paris), this laboratory provided personnel for the working party investigating hazards of a number of explosives and "near" explosives and seeking to establish an international classification for such materials.

Observatories Branch

The Observatories Branch is concerned with two major disciplines - astronomy and geophysics. There are three geophysics divisions: seismology, which operates 26 seismograph stations as well as an array for the detection and identification of nuclear explosions, and sends field parties to all parts of Canada; geomagnetism, which studies the existing and past magnetic fields in Canada through nine permanent observatories and a major laboratory, and which conducts field surveys in all parts of Canada; and gravity, which conducts field work in all parts of Canada.

It is proposed to construct a major observatory, with the 150-inch Queen Elizabeth II telescope as its principal telescope, on Mount Kobau in south-central British Columbia, and to establish an Institute of Astronomy on the campus of the University of British Columbia. These plans have entailed some reorganization of the Branch. The two previous astronomical divisions in Ottawa have been combined, and a small separate group has been set up for the design of the Queen Elizabeth II telescope.

ASTRONOMY, OTTAWA

This Division comprises the former Divisions of Positional Astronomy and Stellar Physics. During the past 15 months the work of the Division has been directed along the following lines:

Positional Astronomy. Discussion of the final program of observations of the Meridian Circle telescope 1955-1960 was completed and published in the form of a star catalogue. The Mirror Transit Circle, which has replaced the Meridian Circle, was operated for 20 nights early in 1966, but has been out of commission all winter for repairs to electronic parts. Pivot errors were re-examined and the automatic measuring engine improved. A new observing program has commenced.

Time Service. The photographic zenith tube (PZT) was operated every clear night, securing a 12-month total of 200 plates containing 3,897 stars. Each star yields a value of astronomical time and latitude. The time determinations, when compared with an atomic time keeper, reveal random variations in earth rotation. Latitude variations provide evidence of polar wander. The results are studied and form a part of the quarterly Time and Latitude Bulletin. They are also supplied in weekly summaries to the Bureau International de l'Heure, Paris, and the International Polar Motion Service, Tokyo. The observatory caesium standard was co-ordinated with others on June 19, 1966, by the international flying-clock experiment by Hewlett Packard. CHU, operating continuously on the three frequencies 3330 kHz, 7335 kHz and 14670 kHz, was improved with a rubidium atomic standard. Time to the millionth of a second is maintained by the official custodian of time for Canada.

Solar Physics. A solar-flare program was continued for part of the year. Site-testing equipment was designed and used on Mount Kobau and at Ottawa, demonstrating the great superiority of the higher location for certain phases of solar research. V. Gaizauskas is spending the current academic year at Kitt Peak Observatory studying the design and operating characteristics of large solar telescopes.

Meteor Physics. Photographic study of meteors and the upper atmosphere was continued at the Alberta meteor observatories. Special preparations to observe the most spectacular display of Leonids in more than a century were foiled by clouds. Further diamond drilling at West Hawk Lake established the underground profile and provided an improved estimate of the size of this ancient meteorite crater. Staff members interviewed the public and made field searches and calculations to recover probable meteorite falls in Quebec, Ontario, and Alberta. A few small fragments of the Alberta fall were recovered and more recoveries were expected in the spring of 1967. Plans are well advanced for a prairie network of camera stations to aid meteorite recovery.

Public Relations. The scope of duties performed by this section has continued to increase, and the educational facilities have been broadened to cope with the demands. There has been a steady growth in the number of requests for popular material by mail and telephone. Additional assignments have been undertaken, assistance given to other agencies and specialized information prepared. The facilities of the Ottawa Observatory have been organized for the regular Saturday evening public visits and the mid-week educational tours. The growing popularity of astronomy has increased the demand for Observatory tours beyond the capacity of the present staff. Approximately 60 requests have had to be refused during the period September 1966 to March 1967. Even so, senior scientific staff members have been pressed into service in exceptional cases. Considerable time and effort has been spent in the preparation of new display material and models, in which bilingual legends have been introduced. One model, illustrating solar, meteor and radio astronomy has proven to be particularly useful since the level of interests of visitors ranges from elementary school students to university graduates and visiting scientists. The section co-operated with the Department in preparing and manning a display on careers in astronomy and geophysics for "Career Expo '66", held by the Ottawa Collegiate Board in May.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY,
PENTICTON, B.C.

A complete survey of the radio emission from the sky at a frequency of 22 MHz is continuing. Most regions of the sky have been observed and work is progressing on the reduction of the data. Several regions have been mapped in detail, and accurate flux densities for several hundred radio sources have been measured. New apparatus is being built to enable the antenna beam to scan rapidly in declination.

Results from the 10 MHz studies have been encouraging and flux densities have been measured for over 150 sources. A new improved receiver system has been placed in operation which records eight beams simultaneously. An absolute measurement of the fluxes of Cygnus A and Cassiopeia A at 10 MHz has been made.

A survey of the continuum radiation in the vicinity of 1420 MHz, using the 25.6-metre paraboloid, is nearing completion. A number of new sources discovered at DRAO in this survey have subsequently been observed with the 46-metre paraboloid of the National Research Council, at 3200 MHz.

A 100-channel spectrometer designed principally for the study of neutral hydrogen emissions has recently been completed. A new receiving system is being built as a joint project with the Department of Physics at the University of British Columbia to search for undiscovered spectral lines in the 1-4 GHz range. The Observatory is collaborating with NRC, the University of Toronto and Queen's University, in a long-baseline-interferometer experiment designed to measure the angular diameters of quasars by observing these sources simultaneously at DRAO in British Columbia and the Algonquin Radio Observatory in Ontario.

The solar-patrol work at 3200 MHz, operated as a joint project with NRC, is continuing.

An entirely new field of investigation was initiated during the year to measure radio pulses originating in extensive air showers (cosmic rays). This has been undertaken as a joint project with the Department of Physics, University of Calgary, and uses a portion of the existing 22 MHz aerial array.

DOMINION ASTROPHYSICAL OBSERVATORY,
VICTORIA, B.C.

The basic programs of the Observatory's research continued as in past years. Much new instrumentation is under construction and

most of it is ready for testing. As a result it is expected that many of the current programs may be extended to fainter stars and new programs will be implemented.

The sudden death of the Director, Dr. R.M. Petrie, was a major blow to the Observatory and to its staff, but it is felt that his memory can best be honoured by continuing and extending the research programs he began. Work on the Queen Elizabeth II 150-inch optical telescope has continued almost without interruption because Dr. Petrie has provided an excellent theoretical foundation for the project.

During the year the spectrographs attached to the 72-inch and 48-inch telescopes were used on nearly every clear night; the 72-inch telescope was used on a few nights for direct photography and the 48-inch telescope was also used for photometry to measure the colours of stars. Observations were made on 139 nights at the 72-inch telescope and 137 nights at the 48-inch, with a total of 1,476 spectrograms being obtained. These plates are measured on special instruments, many of which have been made for the purpose in the Observatory shops. The results are analyzed to give information concerning the radial motions of the stars, and hence the structure of our Milky Way, the distances of the stars, the structure of their atmospheres, their chemical composition and the evolution of stars and galaxies.

Several investigations and results obtained during the past year should be mentioned. A new value for the period of rotation of our galaxy has been determined and will soon be published. From investigations of double stars, for which a new catalogue is being prepared, it is found that about one third of all "binary" systems are at least triple, and one quarter of "triple" systems are quadruple; this result is important in discussions of the formation of stars. The correlation of rotation with helium content in the hot stars seems to indicate that helium may separate from the more abundant hydrogen in slowly rotating stars. In studies of giant cool stars which are eclipsed by smaller hot stars, evidence for clouds or prominences has been found; the lifetimes of these clouds may be a week or more. Several new and possible members of a rare group of stars with abnormal carbon abundances have been found.

Work on new instrumentation for the telescopes was a major feature of the year. A new spectrograph for the 72-inch telescope which will increase its efficiency by a factor of two was built and is ready for testing. A new large mosaic of optical gratings was prepared and is also being tested. An image-intensifier tube, which amplifies starlight electronically, thus gaining a factor of ten over photographic methods, was lent by the Carnegie Institution of Washington and is ready for testing. A new method was devised for using the starlight which is usually wasted when it enters the spectrograph.

More than 25,000 persons visited the Observatory and 5,000 attended public observation periods, including special tours by youth and educational groups. Staff members gave 28 lectures to local organization, including 14 at the University of Victoria. Astronomical information was supplied to representatives of the press, radio, and other groups as requested.

THE QUEEN ELIZABETH II TELESCOPE, MOUNT KOBAU, B.C.

A feasibility study which will provide detailed planning on the telescope as well as for other developments on Mount Kobau has been prepared and was submitted at the close of the period under review. It provides an estimate of costs and recommends methods of procedure. A fork mounting has been found most suitable at our latitude and the study shows that its construction is quite feasible.

The fused silica mirror blank, being constructed in the United States, was making good progress and was expected to be available late in 1967. Construction has been delayed on the optical shop which will shape and polish it, but the necessary optical equipment has all been ordered. Our opticians have been working on large mirrors in the United States to gain experience. The major work of preparing the mirror will begin without delay once the optical shop is ready.

SEISMOLOGY

New seismic observatories were brought into operation at Suffield, Alberta (in co-operation with the Defence Research Board), and Mica Creek, British Columbia, near the site of Mica Dam on the Columbia River. A local seismic station at Banff, Alberta, was closed down. The total number of seismic stations now operated by the Department is 23 first-order stations, complemented by 3 second-order local stations.

The strong-motion network in western Canada has been extended: six stations are fully equipped and some 22 locations have now been instrumented for detailed earthquake-zoning studies.

Considerable progress has been made in the preparation of a new earthquake-zoning map for Canada for National Building Code purposes in defining earthquake loads. The proposed new zoning is based on a theory which uses the catalogued knowledge of the locations, sizes and characteristics of all Canadian earthquakes determined by the Division. It is being evaluated on an experimental basis in co-ordination with the National Committee for Earthquake Engineering. A definitive revised quantitative map should be adopted nationally within two years. Meanwhile, the investigation of a unique sequence of more than 2,000 micro-earthquakes, which occurred in the Northwest Territories during 1965, is nearing completion. Seismic regionalization studies in eastern Canada have been extended. No major earthquakes occurred in Canada during the year.

The Division experienced another increase in requests for advice and quantitative earthquake-risk estimates for engineering, safety and insurance purposes, including information for a number of major critical government-proposed installations.

International co-operation in the study of earthquakes continued at a high level, and the availability of Canadian records and data for national and international research was enhanced by a number of major organizational changes.

A milestone was passed in the automatic processing by digital computer of seismic data from the medium-aperture seismic array at Yellowknife, N.W.T. Detection levels and location accuracies were determined and published, and plans made to increase this work with an "in-house" analogue-digital processor. The results were of great significance to the internationally discussed proposals for the enhanced exchange of seismological data for nuclear detection and national identification.

Fundamental research in the mechanism of earthquakes, in surface-wave dispersion, and in the character of seismic-body-wave signals continued. The Division developed digital library files of data for intensive automatic processing.

The reorganized crustal-seismic-refraction group was very active. A major experiment was completed in the Northwest Territories, serving the additional purpose of calibrating the Yellowknife array. This highly successful experiment was probably the largest one ever undertaken by any group with its own resources in the western world. In addition, an unreversed profile nearly 500 kilometres long was shot across British Columbia, and the results of much work in that province were published. Finally, a new technique for determining structure inside the earth to depths of a few hundred kilometres was developed and published.

The heat-flow section installed thermometer cables in two abandoned oil wells in the Northwest Territories. Three holes were drilled in northern British Columbia, in an experiment designed to search for anomalously high heat flow in a volcanic area. Instrumentation was developed for measurements in a group of deep holes

in the Sudbury area, in order to study the effect of the retreat of the ice of the last ice age.

A number of technical papers were read at scientific meetings, and many papers on seismology and the physics of the earth's interior were published.

GEOMAGNETISM

To keep track of the slow changes in the direction and intensity of the geomagnetic field, careful measurements are made every few years at some 100 repeat stations, uniformly distributed over Canada. During 1966, 21 repeat stations were occupied, mostly in the Yukon and Northwest Territories, with a few in Alaska, British Columbia, Alberta, and Newfoundland.

No airborne magnetic surveys were made in 1966, as the staff worked on the reduction and interpretation of data from the joint Canadian-Scandinavian three-component airborne survey carried out at the end of 1965. Preliminary results have been sent to the five Nordic countries participating in the project. New methods have been evolved, making use of the Department's computer, for detecting errors in the data, carrying out a potential analysis of the observed field, and presenting anomalies in graphical form.

Time variations of the geomagnetic field were recorded continuously at nine permanent magnetic observatories: at Alert, Mould Bay, Resolute Bay, and Baker Lake, all in the Northwest Territories; at Great Whale River in northwestern Quebec; at Churchill, Manitoba; at Meanook, 100 miles north of Edmonton; at Victoria, B.C.; and at Agincourt, near Toronto. Surveys were conducted to choose the location of a new magnetic observatory in the vicinity of St. John's, Newfoundland.

A contract has been let for the construction of new geomagnetic laboratories on a 200-acre site, 10 miles east of central Ottawa. The complex consists of a main building, containing instrument-development laboratories, darkrooms, offices, and a machine shop, and 15 small isolated buildings of non-magnetic construction. It will replace the present geomagnetic laboratory on the Prescott Highway, Ottawa, and the magnetic observatory at Agincourt which must be abandoned because of increasing industrial interference. It will also provide improved facilities for palaeomagnetic research, both for the Observatories Branch and the Geological Survey, and permit more efficient training of personnel.

During the summer of 1966, four temporary observatories, recording both magnetic and earth-current variations, were operated in a line extending from St. John's, Newfoundland, to the north end of Cape Breton Island. Later the stations were moved to give a line north from St. John's to Goose Bay. The purpose of this experiment is to study the electric currents induced in the earth's crust and upper mantle by natural geomagnetic disturbances. Theoretical models of various underground distributions of electrical conductivity are tested in an attempt to explain the observed magnetic and electric fields. Since electrical conductivity depends on the composition, structure, and temperature of the rocks, such experiments provide a method of discovering the properties of the crust at great depths. Analysis of the records indicates the presence of an induction anomaly of a type often found at the edge of continents. A similar investigation continued in southern British Columbia and Alberta, in co-operation with the University of British Columbia.

Studies continued of the natural magnetization of sedimentary rocks collected in the Maritimes and Quebec. By carefully controlled experiments in which the rock samples are subjected to high temperatures and artificial magnetic fields, it is often possible to recover the direction of the magnetic field which existed when the rocks were formed. In this way, the history of the geomagnetic field can be traced through geological time, and theories such as the hypothesis of continental drift can be tested.

GRAVITY

During 1966, emphasis continued to be placed on the measurement of the gravity field within Canada. The field program included observations to maintain gravity standards both in Canada and in other parts of the world as recommended by the International Union of Geodesy and Geophysics, and observations to map in detail the regional gravitational field in Canada. These field projects were carried out in many parts of Canada, and both automobile and aircraft were used for transportation. The highlights of the field program are as follows:

(1) A regional gravity investigation of the Precambrian areas of the Northwest Territories was completed between latitudes 61°N and 70°N and longitudes 100°W and 120°W, and included a detailed investigation of the boundary between the Bear and Slave geological provinces.

(2) As a preliminary to a major regional study in the Cordilleran region, 800 observations were made along three traverses in central British Columbia.

(3) As part of the Polar Continental Shelf Project three gravity traverses were carried out over the continental shelf north of Prince Patrick Island, and regional surveys were conducted on the sea ice west of Melville Island, on Ellesmere Island, and on Baffin Island.

(4) The Branch's program of underwater gravity measurements in the Gulf of St. Lawrence continued with regional measurements west of the island of Newfoundland.

(5) The long-term program to determine fluctuations of elevation of the Penny Ice Cap on Baffin Island also continued. The gravity measurements first carried out in 1962 were repeated in 1966.

Excellent progress has been made with structural interpretation and in theoretical studies to evaluate and develop methods of quantitative analysis of gravity data. Approximately 20 scientific papers covering a wide range of topics were either completed or published in 1966. Included were papers on crustal structure in Hudson Bay, crustal structure in Newfoundland, the analysis of gravity measurements at sea, terrain corrections and automated methods of gravity interpretation.

The large volume of data resulting from the gravity surveys and the computations necessary to analyze and interpret the field observations have required extensive use of computers. In the interest of efficiency this Division began the development of a comprehensive data and program library which will be used on a large computer. Complicated operations involving the use of difficult programs and/or difficult sets of data will be initiated with the same ease as a single operation on a single set of data.

During 1966 the investigation of craters of possible meteorite origin continued. Diamond drilling was completed at West Hawk Lake, Manitoba, and Deep Bay, Saskatchewan. Laboratory investigations continued with detailed measurements, using optical and X-ray equipment, being carried out on quartz, feldspar and other minerals from twelve Canadian craters at which shock effects due to impact have been recognized.

Instrumental development included the establishment of an earth-tide laboratory 30 miles north of Ottawa and the virtual completion of the reconstruction of the Canadian pendulum apparatus. The earth-tide laboratory is equipped with two horizontal pendulums to measure crustal tilt and a gravimeter to record earth tides. The pendulum apparatus underwent a series of tests between Ottawa and Almonte, Ontario. Minor adjustments to the apparatus were being made at the year's end.

Geographical Branch

PHYSICAL GEOGRAPHY DIVISION

Baffin Island. This was the largest of all the Branch field parties. It investigated the geomorphological, glaciological and post-glacial characteristics of the whole central part of Baffin Island. Work was mainly concentrated on the Barnes Ice Cap and in the area between it and the northeast coast. Observations and measurements of mass balance and of movement continued on the Barnes Ice Cap and on Decade Glacier at the head of Inugsuin Fiord which is being studied as a contribution to the Hydrological Decade. Observations were also made for a study of moraines, both beneath the waters of one of the perimeter lakes of the Barnes Ice Cap. This is part of a study to determine the location and probable date and manner of the separation of the Baffin Island ice sheet into the proto-Barnes and proto-Penny ice caps. A landscape survey was made by aircraft and photographic coverage was taken to permit continued qualitative evaluation of the area. A reconnaissance was made of the outwash plains at the head of Ekalugad Fiord on the east coast, and the studies of glacial chronology of the isostatic rebound of the area were continued as far as Cape Hooper at the southern limits of Home Bay. Other studies included a palaeoecological examination of the sediments and fossil molluscs in a cliff section at Cape Christian; observations and measurements of till fabrics and pebble roundness; sedimentary aspects of present-day boulder fans; a detailed geological study at the head of McBeth Fiord; a continuation of last year's observations of movement of solifluction tongues and talus slopes, and a special helicopter-supported examination of mountain tops to determine the upper limit of continental glaciation.

To further the study of the glacial history of the whole eastern Canadian Arctic, a field trip was made to the Ottawa Islands in the late summer to observe the evidence of isostatic uplift in that area and to study the palaeontology of shell beds. The operation was conducted with support from three other branches of the Department and in association with two universities.

The Cypress Hills. Studies continued of the structural geomorphology of the area and of the soil-landform relationships on the summit surface and pediment slopes. Soil samples were collected for laboratory analysis and radiocarbon dating. Work also continued on the mapping and examination of prairie mounds. Preliminary work was carried out for long-term studies of the sequence of terraces along the major drainage lines of the area and their relation to valleyside debris as well as for the mapping and examination of soils and gravels in the area.

Data obtained from 12 Class A weather stations established by the survey, as well as data supplied by the Department of Agriculture, are being used to study the difference between the climate of the Cypress Hills and that of the surrounding prairies. Microclimatic studies are being made at selected areas as well as comparisons between the behaviour of dynamic phenomena such as the vertical flux of momentum, heat and water vapour within the forests of the Cypress Hills and on the adjacent prairies. The climatic effect of various local landforms is being studied from data obtained from aircraft equipped with various types of recording instruments.

Studies were begun on the historical geography of the general field area with a view to evaluating man's impact upon the recent evolution of the landscape.

The Mackenzie Delta. Further observations were made in the continuing study of the advance of permafrost under shallow or partially drained lakes and of other phenomena common to areas of frozen ground. Studies were made of the electrical resistivity in frozen ground and of the summer soil-moisture regime in hummocks and tussocks. Observations were made of the climatic transition evident from the head of the Mackenzie Delta to the coast at Garry Island, and data for the heat-budget studies being made at Hidden Lake and another small unnamed lake in the delta were recorded.

The dates and patterns of freeze-up and break-up along the Mackenzie Waterway were again noted.

Polar Continental Shelf Project. For the sixth season, participation of the Geographical Branch continued both in the glacial and periglacial studies and in research into the characteristics of sea ice in the area of the Queen Elizabeth Islands. The 1966 season was the longest (five months) and most rewarding of all those in which the Branch has shared in the sea-ice project.

In addition to the above projects, survey work was carried out with the aim of bringing the geographic data on Southampton Island up to date, and further data were collected on Mount Seymour, B. C., for the study of the processes and effect of snow creep.

Office studies in the Physical Geography Division concerned:

Prediction methods of estimating from heat-budget data the onset of ice in the Beauharnois-St. Lambert section of the St. Lawrence Seaway.

The relationship between ice-sheet thickness, marine limit and isostatic uplift on the Canadian mainland and the arctic islands exclusive of the Queen Elizabeth group.

Changes in pebble shape in different arctic environments.

The relationship between present and past glaciations using trend-surface techniques.

Work on the glossary of periglacial phenomena which had been in preparation for some time as a joint French-English project under Dr. Louis-Edmond Hamelin of l'Université Laval and Frank A. Cook of the Geographical Branch, had to be reassessed as a result of the death of Mr. Cook on March 25, 1966. A final editing of the already-completed English section was made and passed, together with the illustrations, to Dr. Hamelin who has assumed responsibility for publication of the project through the Centre d'Etudes Nordiques at l'Université Laval.

REGIONAL AND ECONOMIC GEOGRAPHY DIVISIONS

Atlas of Canada. The Atlas of Canada is the major undertaking of the Division of Regional Geography. The atlas presently in compilation is part of a continuing atlas program. The new atlas will have contents comparable to the 1957 Atlas of Canada, but will be of smaller dimensions, with a two-paged spread measuring 20 x 15 inches. It will, therefore, be more portable than the 1957 atlas. It is planned that the first edition will be issued as loose-leafs in a specially designed box, but page layout is organized to facilitate binding of later editions. Publication in French and English is expected in 1968. Several special maps from the atlas covering population, territorial evolution, and lakes, rivers and glaciers, will be released for distribution in 1967. Distribution of the finished atlas will be by the Queen's Printer.

Prairie Provinces Regional Economic Studies. Field work for this project, undertaken with the co-operation of other government departments and outside agencies, has been completed. The information gathered covers many facets of Prairie activity and development, and maps and text evaluating these data are now being prepared.

Agricultural Development Possibilities in Southeast Renfrew County. This survey, begun in 1964, is a study of the possible development of good agricultural land in the county and an evaluation of the use, other than agricultural, which might be made of land unsuitable for farming. Field work has been completed, the statistical data are in the process of being analyzed and the final report is in preparation.

Present Land-Use Survey (a part of the Canada Land-Use Inventory being compiled by ARDA). The purpose of this survey is to provide maps from which a reliable estimate can be obtained for large-scale planning of the extent and location of land presently used in various categories such as urban, recreational, cultivation, forestry and grazing. The information is obtained from air photographs, supplemented by selected field checks and such relevant land-use surveys as have already been made by other agencies. Surveys and mapping have been completed for about 70 per cent of the Maritimes - exclusive of Newfoundland - and for about 50 per cent of Ontario. In Quebec, where the work is approaching 50 per cent completion, the surveys have been concentrated mainly in three areas: along the north shores of the St. Lawrence and Ottawa rivers, in the Eastern Townships and in the Gaspé Peninsula.

Three other ARDA projects are in progress in Nova Scotia:

Compilation of an inventory of the Nova Scotia shoreline for purposes of possible recreational development.

A survey of the potential tourist industry development in Guysborough County.

A survey to assist in planning a farm-consolidation program and community woodlot development in the nine eastern counties. This also includes a survey of the blueberry industry in Cumberland and Colchester Counties to assess its potential for acreage expansion.

Two Newfoundland projects were completed and the results published as ARDA Study 1043, "Forest Utilization, Great Northern Peninsula, Newfoundland", 1965, and ARDA Study 1043, "Fishery Utilization, St. Barbe Coast, Newfoundland", 1966.

The Survey of Urban Characteristics. This is an inventory of selected urban characteristics in 16 major Canadian cities for the Emergency Measures Organization, the results for each city being displayed on 32 maps at a scale of 1:25,000. Surveys and mapping were already completed for Vancouver in 1965, and survey work for Toronto is completed and 22 of the map sheets are printed. The survey work for Montreal, Ottawa and Windsor is completed and maps will be prepared as soon as possible. Survey work for Hamilton is in the final stages.

Survey of the Urban Structure of the Maritime Provinces. This study for the Atlantic Development Board was begun in the summer of 1966. It aims at evaluating the potential of maritime urban centres to absorb investment and at suggesting which centres are most in need of capital infusion. It considers the type of establishment and the employment structure of each community and examines its socio-economic characteristics, analyzing them by factor analysis for comparison with the economic well-being of other centres. Finally, it intends to determine, by means of field surveys, the business methods and attitudes, the population movement and the extent and fluctuation of the trade areas of each town. The preliminary report for Newfoundland has been completed.

Atlantic Provinces Resources Map. Compilation has been completed on the map of economic, human and natural resources of the Maritimes which has been revised by the Geographical Branch for the Atlantic Provinces Economic Council. It is expected the map will be published - in both English and French versions - early in 1968.

Harbours. The analysis of the movement of commodities through the ports of Halifax and Saint John, begun during the winter of 1964-65, has been completed and the final comprehensive report delivered to the National Harbours Board.

TOPONYMY DIVISION

During 1966 the staff of this Division investigated nearly 20,000 geographical names and answered over 600 enquiries. Field investigations of geographical names of counties in eastern Ontario were completed in 1966 and studies made of the names in parts of Prince Edward Island and in the western part of Carleton County, Ontario.

Work was begun on the revision of the Gazetteer of Manitoba and is still continuing on the Gazetteer of Quebec. The Gazetteer of Newfoundland is almost completed, and the revised Gazetteer of British Columbia is now with the printer.

CANADIAN PERMANENT COMMITTEE ON GEOGRAPHICAL NAMES

This Committee deals with all questions of geographical nomenclature affecting Canada and is composed of federal and provincial representatives concerned with nomenclature. At the plenary session held in Victoria in September 1966, it was agreed that the pronunciation of geographical names should be a concern of the Committee, that a sub-committee on undersea-features nomenclature be established, and that steps be taken to initiate a punch-card system for geographical names.

NATIONAL ADVISORY COMMITTEE ON GEOGRAPHICAL RESEARCH

During 1966, the National Advisory Committee held two meetings, on February 4, 1966, and May 25, 1966. Working committees were set up to inform and advise the main group on matters relating to regional analysis, resource geography, remote sensing and the processing of statistical data. A grants sub-committee was appointed and guidelines were laid down to facilitate the advertising and awarding of research grants. Twenty-three grants, ranging in value from $200 to $2,000, and totalling $25,000, were awarded in 1966.

Polar Continental Shelf Project

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Canadian Arctic Islands and mainland, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Arctic Archipelago and the waters between them and other areas that may be of special interest. The Project serves in part as the agency through which the researches and surveys of other branches of the Department of Energy, Mines and Resources, and of other government departments, are carried out in the Arctic Archipelago and in the Arctic Ocean; in part it carries out, with its own personnel, work that is unique within the Department; and it also provides facilities and support for approved university researches in the area.

The main base of 1966 field operations was at Mould Bay, on Prince Patrick Island, with a secondary base at Alert on Ellesmere Island. Up to ten temporary or mobile camps were established as the work required. Field investigations were carried on from early March until mid-October, and engaged about 90 persons, exclusive of contract aircraft engaged for short periods or of university parties to whom minor though important support was given. In addition to the work initiated and carried out by the Project itself, the activities of the Polar Continental Shelf Project contributed to the work of four branches of the Department (Geological Survey, Marine Sciences Branch, Observatories Branch, and Surveys and Mapping Branch) as well as that of eleven other departments and institutions.

As a supplement to the field activities, the Polar Continental Shelf Project continued its investigation and development of special equipment and techniques for research in polar regions. Further progress was made in meeting the problems of high-speed hydrographic surveying in Arctic waters, in electromagnetic wave propagation for position-fixing over sea ice, in the development of ocean-floor heat probes, and geomagnetic and magneto-telluric equipment.

The principal activities of the Polar Continental Shelf Project in 1966-67, by subject, were:

Aeromagnetic Surveys. Measurements of the total residual magnetic field as recorded from a height of 1,000 feet above the surface were made over the continental shelf and continental slope offshore from Brock and Prince Patrick islands, and over southern Prince Patrick Island, Fitzwilliam Strait, Crozier Channel and Eglinton Island. Poor weather and unsettled geomagnetic conditions combined with equipment difficulties to limit severely the amount of survey.

Geodetic Surveys. The precise survey of a geodetic control network between Ellesmere Island and northwestern Greenland continued. This survey, when completed, should determine the horizontal position of stations on Ellesmere Island, with respect to those on Greenland, with sufficient precision that subsequent surveys of similar accuracy, planned to be repeated after 10 and 20 years, will show whether there has been significant relative movement between the islands. This work is part of a long-term multi-disciplinary investigation of the crustal and structural relationships in the Nares Strait region.

Geology. Samples of sediments were taken from the sea floor on the continental shelf and continental slope offshore from northern Prince Patrick Island, in a program designed to provide information on the present and geologically recent conditions of sedimentation and the recent geological history of the area. A similar but more detailed study was continued in Hecla and Griper Bay, northern Melville Island, to investigate the present and past sedimentation and faunal record, and the conditions under which the present bottom-dwelling organisms are living, in a protected body of water under a continuous ice cover. Logistics support and field facilities were provided to parties of the Geological Survey of Canada and other institutions studying terrestrial geology.

Glacier Physics and Glaciology. The detailed investigations of the Meighen Icecap continued, with vertical temperature and deformation profiles measured in the borehole that penetrates the icecap near its apparent thickest point, and with crystallographic and fabric studies on the ice cores collected in 1965 from the borehole. Routine glaciological measurements, by a survey of the previously established stake networks, were continued on the Meighen and Melville Island icecaps. A contract was let for low-altitude aerial photography of the Melville Island icecaps; ground survey control was run and photographic target markers were prepared, but owing to poor weather the snow cover did not disappear sufficiently from the icecap to permit photography.

Logistics support was provided for glaciological studies by McGill University on Axel Heiberg Island and by the Arctic Institute of North America on Devon Island.

Measurements were made of the surface displacement of boreholes in Athabasca Glacier, Alberta, continuing a series that was carried on annually from 1959 to 1963 inclusive, in connection with studies of the flow law in a temperate glacier; and instruments were installed in certain boreholes to measure the vertical temperature distribution in a glacier near its melting point, as a comparison with the "cold" Arctic glaciers.

A visit was made to Steele Glacier, Yukon, to observe the reported surge of the tongue of this large sub-Arctic glacier. Photography contracts were let within a few days and two sets of photographs, 28 days apart, of the rapidly changing glacier were obtained in August and September. The Project played a part in arranging for the subsequent study of this glacier, which has included periodic observations and oblique photography during the winter by the Water Resources Branch; the drawing up of maps by the Surveys and Mapping Branch; and a ground control survey by the Army Survey Establishment in 1967, as well as further aerial photography.

During a brief field trip to Antarctica, a member of the Project investigated the structure and behaviour of certain glaciers in the "dry valley" region of Victoria Land, took part in studies of snow accumulation problems as they affected the maintenance of research stations on the icecap, and contributed to surveys designed to measure the stress in a floating ice shelf.

Gravity Studies -- (See Observatories Branch.)

Hydrographic Survey. The bathymetric survey of the continental shelf and continental slope, and of the straits and sounds between the western Queen Elizabeth Islands, continued, with through-the-ice sounding from spot landings by helicopters on a grid spacing of 7 to 10 kilometres over about 35,000 square kilometres of the Arctic Ocean offshore from Prince Patrick Island. Decca Lambda position control, based on Prince Patrick and Brock islands and tied to the Shoran geodetic network, was used. This work is being compiled for publication on a scale of 1:500,000.

Periglacial Studies. A detailed two-year study was completed of the periglacial features of the Arctic coastal plain and adjacent parts of Prince Patrick Island. Pingo-like forms, sand dunes, raised and dissected deltas, slopes and scarps were investigated as to their structure, mineral and textural composition, and method of formation. This work was supported jointly by the Polar Continental Shelf Project and the Canada Council, and was carried out by a geomorphologist from the University of Liege, Belgium.

Radio-Wave Propagation Studies. A series of experiments was carried out, with the assistance of a party from the Defence Research Telecommunications Establishment, to determine radio-wave transmission properties over the Lincoln Sea and Robeson Channel ice at different frequencies and throughout the year with changing ice conditions. The results have shown significant effects of sea ice on radio transmission, which will have important and in some cases inhibiting consequences on electronic survey and navigation systems in polar regions.

Sea-Ice Studies. Systematic studies were made of all major waters of the Queen Elizabeth Islands and of the adjacent Arctic Ocean and Parry Channel, Beaufort Sea and Amundsen Gulf throughout the season of significant sea-ice activity. Information was collected on the composition, break-up, amount, distribution, dispersal and formation of the sea ice, and of the origin, movement, and disintegration of certain tabular icebergs or "ice islands". It has proved possible to follow the movement of the same ice throughout the season and from year to year, and to record its progressive and cyclical changes. Information is collected relating the behaviour of the sea ice to meteorological and oceanographic factors; this, it is hoped, will lead to a better understanding of the causes and controls of sea-ice development and movement and thus, in turn, to better forecasts of ice conditions.

Sub-Ice Acoustics. Logistics support and field facilities were provided for an investigation, undertaken by the Pacific Naval Laboratory of the Defence Research Board, of the transmission of sound under unbroken pack ice over deep water, offshore from Prince Patrick Island.

Topographic Surveys. Location surveys were completed for the establishment of the Decca Lambda survey and navigation chain to cover McClure Strait. Surveys were run to provide additional ground control for aerial photography, and to record glacier movement, in the icecap area of Melville Island. Glaciological surveys were carried out in the Meighen Icecap.

MINERAL DEVELOPMENT GROUP

Mineral Resources Division

The value of Canada's mineral production for 1966 surpassed the $4 billion mark for the first time in the country's history. At $4,003 million, it represents an increase of 7 per cent over the 1965 production value of $3,744 million. Each of the three mineral-industry sectors set new highs in 1966, with metallics increasing to $1,995 million from $1,907 million, industrial minerals to $843 million from $760 million, and mineral fuels to $1,165 million from $1,076 million in 1965. Mineral exploration and development was extensive and widespread in all producing provinces and territories. Development of properties for production continued at high levels, assuring continued expansion and diversification of Canada's mineral industry in the years ahead. Minerals and mineral products continued to be one of the mainstays of Canada's export trade, and in 1966 crude and fabricated mineral materials accounted for over 30 per cent of total Canadian exports.

In the field of offshore exploration, more than $20 million has been spent to date by the various companies concerned, and the tempo of offshore activity is increasing. Approximately $8 million was spent during the past year.

The work of the Mineral Resources Division lies mainly in the field of resource-economics and is divided into two categories - operational and advisory. Mineral specialists of the Division conduct field and office investigations directed toward both basic and applied engineering-economic research on a wide range of mineral commodities and problems. The work covers all aspects of the mineral industry from resources through exploration, development, mining, beneficiation, smelting and refining, and transportation, to pricing and marketing. This basic research is essential for the preparation of reports for general distribution and for providing informed assessments and advice to government departments and agencies, industry and the public on mineral and related problems.

Federal responsibilities in the administration and management of non-renewable resources were reorganized at the beginning of 1966 in accordance with Order-in-Council P.C. 1965-2284, December 22, 1965. These responsibilities have been allocated between the Department of Indian Affairs and Northern Development and the Department of Energy, Mines and Resources, so that the former now handles mineral rights in the Yukon, Northwest Territories, offshore Arctic and Indian Reserves, and the latter the federal interests offshore from Canada's west and east seacoasts and in Hudson Bay, as well as the federally owned mineral rights in the provinces. The Resource Administration Division was formed in 1966 to handle the mineral-resource responsibilities thus transferred to the Department of Energy, Mines and Resources. The Mineral Resources Division now consists of the Research and Special Projects Section, Materials Section, Taxation and Legislation Section, and the Resource Administration Division.

General Advisory Activities. Research continued in many mineral matters of national and international concern for the preparation of government submissions. By means of basic-resource investigations and economic research, officers of the Division are able to advise the Department on a wide variety of mineral matters of national importance, including mineral taxation and legislation. Service rendered by the Division from January 1, 1966, to March 31, 1967, included continuing assistance to the Canadian Tariffs and Trade Committee representing Canada at Geneva in discussions relating to the General Agreement on Tariffs and Trade (GATT); advice on the implementation of Canadian export controls on copper; an estimate of Canadian tin consumption for 1966 for the meeting of the International Tin Council; a study on the effect of higher tolls on Canadian iron-ore passing through the St. Lawrence Seaway and Welland Canal to consumers in Canada and the United States; a brief in support of mine access roads; an appraisal of the past and present mineral-resource-development policy of Newfoundland and Labrador with recommendations for the future; and the commencement of a similar study on New Brunswick. Other studies included an economic evaluation of the Anvil lead-zinc property in the Whitehorse Mining District of the Yukon Territory, taking into consideration various transportation and processing alternatives, overall operating costs and marketing expectations. An economic evaluation was also made of the benefits that might be expected from the opening up of the iron-ore deposits in the Mary River area of Baffin Island, having regard to various cost and marketing assumptions.

The Division provided other government departments with analyses and advice on mineral developments so that assessments could be made of the need for public services such as roads, airstrips, docks and buildings in specified areas. This work requires resource-economic appraisals of all pertinent factors from resource development through processing to marketing.

Analyses and recommendations were provided to the Department of National Revenue with respect to tax benefits under the Income Tax Act which are applicable to the mineral industry. Reports were prepared on 29 applications for three-year tax exemptions. One application for certification as operators of an industrial-mineral mine on a non-bedded deposit was processed.

During the second half of 1965, the Chief of the Division and a member of the Division's Research and Special Projects Section were seconded to work with J.R. Donald, Special Consultant on Coal to the Minister of Trade and Commerce, on the Cape Breton coal problem. This assignment was completed in the second quarter of 1966, but follow-up work continued throughout 1966 and early 1967 relative to Dr. Donald's report and its study by the Government.

Late in 1966, the Assistant Chief of the Division and a member of the Division's Research and Special Projects Section attended mineral-industry hearings as special minerals advisers of the Royal Commission on Economic Prospects of Newfoundland and Labrador. Hearings were held in St. John's, Wabush and Labrador City. Follow-up advisory work continued into the first quarter of 1967.

International Activities. Officers of the Division presented reports at meetings of several international organizations concerned with minerals and mineral trade. These included special mineral-industry committees of the Organization for Economic Co-operation and Development (OECD); the steel committee of the United Nations, Economic Commission for Europe (ECE); the International Lead and Zinc Study Group; the United Nations ad hoc Committee on Tungsten; and the International Tin Council.

Roads to Resources. The Roads to Resources Program is a national program designed to provide access to areas potentially rich in natural resources. The administration of the agreements, which provide $7.5 million as the federal share for each province, was transferred to the Mineral Resources Division in October 1966. Federal payments to March 31, 1967, were approximately $71 million. The balance, some $4 million, has been committed for the completion of the program in 1968-69.

Foreign Aid Training. The Division, on behalf of the External Aid Office, arranged 58 technical-training programs for foreign trainees and provided consultation on 13 additional applications. These programs were sponsored mostly by the Colombo Plan and took place in the Department of Energy, Mines and Resources as well as in private industry. Nineteen trainees completed training programs in the period January 1, 1966 to March 31, 1967. At the end of the period ten trainees were on study courses and 23 planned programs were awaiting arrival of candidates. In addition, 34 foreign students in attendance at Canadian universities under various technical-aid programs were given summer employment in the Department in fields related to their academic courses. The Division also participated in arrangements to send mineral consultants abroad to advise certain developing countries on mineral policies and projects.

Publications of the Division. Between January 1, 1966 and March 31, 1967, Division personnel completed Mineral Information Bulletins on iron ore, federal taxation and legislation, mercury, the OECD steel industry and preliminary reports on the mineral industry for 1965-66. Other publications completed were nine Operators Lists and the Canadian Minerals Yearbook 1964. Reports on uranium and the mining laws of Canada, as well as the Canadian Minerals Yearbook 1965 were being printed, while work proceeded on the preparation of reports on nickel, beryllium, zinc, copper, molybdenum, manganese, natural gas, fertilizers and stoping practices. Several papers were prepared and delivered at national and international conferences or submitted for publication in technical journals.

Information Activities. The Division has a continuing program of educational filmstrips. During the period, research and scripting was completed by the National Film Board under the direction of commodity officers on two filmstrips, iron and steel and aluminum, designed for use in high schools. Both filmstrips will be in 'kit' form with supporting information and samples. The Division's photographic library and mineral-resource-records centre continued to be enlarged.

Revision and reprinting of the booklet Entrance Awards for Mineral Industry Courses at Canadian Universities and Technical Institutes was completed. The 16th edition of the popular mineral map Principal Mineral Areas of Canada was also completed and received wide distribution.

Mineral Occurrence Index. The Division maintains an index of Canadian mineral occurrences which is available for the use of anyone interested in mining and exploration in Canada. The indexing of Canadian mineral occurrences was begun nearly 70 years ago, and was carried out intermittently until 1959. Since that time work has been continuous. The method of indexing has been changed to conform to the National Topographic System and the index has been reorganized to include a comprehensive summary of the information available on each occurrence with provision for revision and additions as required. At March 31, 1967, the Mineral Occurrence Index contained descriptions of almost 10,000 mineral showings and deposits.

Canada Oil and Gas Permits. Offshore Canada oil and gas permits are issued under the Canada Oil and Gas Land Regulations. They are valid for 6 years with 6 renewals of one year each, and are granted for a grid area or half a grid area. A grid area is delimited by lines of longitude 15 minutes apart and lines of latitude 10 minutes apart, and may range in size from approximately 95,000 acres at 42° 00'N latitude to approximately 60,000 acres at 62° 00'N latitude. The applicant must pay a fee of $250 per permit, and deposits must be made at the beginning of each work period throughout the life of a permit to the full amount of the work requirements at that period. All such guaranty deposits are returned upon satisfactory performance of work, but they are subject to forfeiture to the amount that work requirements are not met. The total amount of work required during the 12-year life of a permit is $2.70 per acre. A permit must be converted to oil and gas leases before commercial production can be undertaken. There are no leases in the offshore areas as yet.

A total of 605 Canada oil and gas permits covering 43 million acres in offshore areas were issued during the past year, as follows:

East coast	588 permits	42,301,906 acres
West coast	7 permits	327,309 acres
Hudson Bay	10 permits	390,828 acres

This brought the number of offshore Canada oil and gas permits (except the Arctic coast) to 2,750, covering 206 million acres, as follows:

East coast	1,650 permits	134,211,815 acres
West coast	279 permits	18,018,562 acres
Hudson Bay	821 permits	53,864,747 acres

On March 31, 1967, the Division held approximately $10 million in the form of guaranty deposits made by permittees against the work requirements of their permit holdings. The total revenues received during the fiscal year 1966-67 on behalf of offshore permits, including permit fees, transfer fees, forfeitures, maps, and exploratory licences, amounted to $154,068.60, most of which was derived from permit fees.

Mineral Claims. Offshore mineral claims are issued for mineral rights other than oil and gas rights under the Canada Mining Regulations. Each mineral claim covers an area not greater than 1,500 feet square (approximately 52 acres). A total of 163 offshore mineral claims were recorded during the past year, of which 84 are located off the west coast and 79 off the east coast. This brought the total number of mineral claims to 286, distributed as follows: east coast, 79; west coast, 142; Hudson Bay, 65. Total revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1966-67 amounted to $817.00.

Federal Lands in the Provinces. Oil and gas leases for lands falling within this category are issued under the Public Lands Oil and Gas Regulations. Each lease comprises approximately 160 acres, is valid for 10 years, and is renewable if capable of production. A fee of $5.00 is payable upon issuance, and there is an annual rental of $1.00 per acre. The rate of royalty payment is 12 1/2 per cent on oil and 15 per cent on gas.

During the past year, 27 oil and gas leases were issued; of these, 16 were in Alberta, 6 in Saskatchewan, and 5 in Manitoba. This brought the total number of federal oil and gas leases in the provinces to 209, as follows: 101 in Alberta; 77 in Saskatchewan; 27 in Manitoba; 4 in Ontario. In addition, there are 5 gas leases and 4 oil leases in Alberta. There are also 3 leases for minerals other than oil and gas - 2 in Ontario and 1 in Saskatchewan. On March 31, 1967, 51 oil and gas leases were productive, as follows: 25 in Alberta; 18 in Saskatchewan; 8 in Manitoba. The total revenues received during the fiscal year 1966-67 on behalf of oil and gas leases, including royalties, lease sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $301,657.62, most of which was derived from royalties.

The Emergency Gold Mining Assistance Act. The Act was extended on December 12, 1963, for four years to the end of 1967 without change in the formula for computing the amount of assistance payable.

The amending legislation restricted the eligibility of lode gold mines commencing production after June 30, 1965. Such mines are eligible for assistance only if they provide direct support to an existing gold-mining community. A gold mine is deemed to provide such support if most of the persons employed at the mine reside in gold-mining communities listed in the amending Act.

The administration of the Act is conducted in the Mineral Resources Division under the direction of the Assistant Deputy Minister (Mineral Development). Gold mines receiving assistance are visited by inspection engineers from the Division who determine the proper classification of exploration and development expenditures. They review and report upon the allowance of costs which are in question. An examination of mining and milling practices and of production and ore-reserve records is part of the inspection. The Audit Services Branch, Office of the Comptroller of the Treasury, examines interim applications and carries out the final audit of each applicant's books of account.

The amount of assistance payable to an operator under the current formula is computed by adding 25 per cent to the product of the rate of assistance and the number of assistance ounces. The number of assistance ounces is two thirds of the total number of ounces produced in the assistance period. The rate-of-assistance factor is determined by taking two thirds of the amount by which the average cost of production per ounce exceeds $26.50. Thus a gold mine

which has an average cost of production less than $26.50 an ounce is not eligible for assistance. The maximum rate of assistance is $12.33 per ounce.

There were 44 lode gold mines and 25 placer gold mines in receipt of assistance during 1965. Seven gold mines had average costs of production less than $26.50 an ounce.

Lode gold mines usually apply for assistance payments on a quarterly basis, while a single annual payment is generally made to operators of placer gold mines. In 1966, 210 separate applications were examined by the Audit Services Branch, approved by this Department and transmitted to the Chief Treasury Officer for payment.

The amount of assistance paid per calendar year since the Act was introduced is as follows:

1948	-	$10,546,315.84	or	3.33	per ounce produced
1949	-	$12,571,456.90	or	3.48	per ounce produced
1950	-	$ 8,993,490.51	or	2.55	per ounce produced
1951	-	$10,728,503.71	or	3.30	per ounce produced
1952	-	$10,845,978.62	or	3.75	per ounce produced
1953	-	$14,680,110.42	or	4.62	per ounce produced
1954	-	$16,259,179.23	or	4.29	per ounce produced
1955	-	$ 8,885,478.73	or	2.97	per ounce produced
1956	-	$ 8,667,235.38	or	3.46	per ounce produced
1957	-	$ 9,679,753.32	or	3.55	per ounce produced
1958	-	$11,420,463.70	or	4.29	per ounce produced
1959	-	$12,001,753.43	or	4.91	per ounce produced
1960	-	$12,362,517.59	or	5.02	per ounce produced
1961	-	$12,666,658.77	or	5.30	per ounce produced
1962	-	$14,355,013.49	or	6.16	per ounce produced
1963	-	$14,397,419.04	or	5.54	per ounce produced
1964	-	$15,069,735.80	or	5.69	per ounce produced
1965	-	$15,686,000.00	or	6.55	per ounce produced
1966	-	$14,834,000.00		Not available	

Explosives Division

The Explosives Division administers the Explosives Act, first passed in 1920, as an instrument of public safety to control explosives manufacture, sale, storage, importation and transportation by road. The Division discharges its task by licensing and inspecting factories, magazines and transportation, assessing new explosives and equipment, contacting representatives from federal and provincial government agencies, explosives manufacturers and construction and transportation industries.

The Division also publishes literature in the form of reports on production, consumption and importation of explosives, accidents in which explosives are involved, and pamphlets on safety, and minimum standards for storage and handling of explosives.

In the past ten years the production of explosives has more than doubled, with corresponding increases in the number of factories, magazines and transportation vehicles.

Many new developments have occurred, such as the introduction of portable mixing units, new techniques in loading blast holes and a much greater variety in the types of explosives.

The output of commercial blasting explosives in licensed factories during 1966 was 300 million pounds, plus an additional quantity of ammonium nitrate and fuel oil estimated at 50 million pounds blended at the site on mining properties.

The number of licensed explosives factories increased to 34. Specialization is as follows:

Military explosives and pyrotechnics	4
Fireworks	2
Commercial ammunition	6
Blasting explosives for sale	18
Blasting explosives for private use	4

The Division issued 1,681 licenses for the storage of explosives and 404 permits for the transportation of explosives by road.

During 1966 there were five fatalities in the use of explosives, compared with eight in 1965. There was one fatality in manufacture and one in the transportation of explosives by road.

For the first time since 1952, misuses of abandoned detonators resulted in death; two young children were killed and 17 others sustained injuries. Forty-four persons were injured by fireworks or home-made explosives.

There were 37 prosecutions under the Act - 16 for illegal storage and 21 for violation of transportation regulations.

The Division maintains offices at three locations: Ottawa, Halifax and Vancouver.

WATER GROUP

Marine Sciences Branch

The Marine Sciences Branch is responsible for the physical survey and research of Canadian coastal waters and of the oceanic areas adjacent to Canada. Through the Canadian Hydrographic Service, it produces nautical charts and associated publications of these and of inland navigable waters. As an extension of its latter role, it provides field support to limnological studies of the Great Lakes. The Branch's oceanographic research embraces physical and chemical studies of the marine environment and of the geophysical and geological properties of the ocean bottoms. The latter studies are oriented toward an assessment of submarine mineral resources.

The extensive and varied activities of the Branch are co-ordinated into three operational regions -- Eastern, Central, and Western -- with a headquarters in Ottawa which provides special and supporting services for the organization as a whole.

In 1966 the Branch's fleet totalled 10 ships, 66 sounding launches and 85 smaller craft. Two helicopters and two chartered vessels were also employed. These vessels were engaged in charting and research of Canadian and adjacent waters from the coast of British Columbia and the western Arctic to the expanses of the western Atlantic. Three new survey and research ships were under construction -- CSS Parizeau and CSS Vector for operation on the west coast, and CSS Dawson for operation on the east coast. These ships were to be delivered in the latter half of 1967. Six new sounding launches of higher speed were purchased. These are substantially increasing the efficiency of hydrographic survey.

HEADQUARTERS

In Ottawa, chart production, and tidal analysis and prediction were emphasized.

Two hundred and eighty-seven charts, including twenty-seven new charts, were published. Over one-quarter million charts, were distributed. Published charts were kept up-to-date by the production of 78 new editions, 97 corrected reprints, 5 supplementary prints and 28 reprints. Of the new charts published, three were medium-scale charts of the Atlantic Coast designed for offshore navigation and fishing, and two were small-craft charts, one covering Lakes Simcoe and Couchiching.

Nine Information Bulletins were revised and published. Of these, 165,000 copies were distributed. A new Information Bulletin was published showing the water routes to Expo '67. This bulletin was received with great enthusiasm by many organizations and tourist bureaus of both Canada and the United States; over 100,000 prints were distributed.

Collation of the bathymetric data of the western Arctic Ocean was continued. Plotting sheets for the quadrant 90°W - 180°W were completed and sent to the International Hydrographic Bureau which acts as the co-ordinator of the General Bathymetric Charts of the Oceans Project.

The predictions in the Tide and Current Tables were prepared by computer programs and the output was used directly in the printing, marking the first time that any country has achieved this degree of automation.

Several major studies in tidal research have been completed, namely, the effect of tidal barriers upon the M_2 tide in the Bay of Fundy for the Atlantic Tidal Power Programming Board and a major text on the analysis of tides, which has been submitted for publication. Studies are continuing on the mathematical modelling of the St. Lawrence River.

The Canadian Oceanographic Data Centre continued to develop its role of a national centre for the processing, storage and retrieval of oceanographic data. It extended its processing of Great Lakes data.

WESTERN REGION

The Western Region includes the Pacific Coast of Canada, the western Arctic and the navigable waters in British Columbia. Its activities, at present, concentrate on hydrographic surveys and tidal-current investigations.

Along the southern British Columbia coast, CSS Wm. J. Stewart continued a survey in the Strait of Georgia (Gabriola Passage to Nanoose Harbour) and commenced a survey of the approaches to Burrard Inlet. CSS Marabell completed a survey at Menzies Bay, as required at new ore-loading dock facilities, and surveys to meet R. C. N. requirements at Uchucklesit and Neroutsos Inlet. A survey was commenced at Prideaux Haven in Homfray Channel.

Along the northern coast the general charting program was continued with CSS Wm. J. Stewart carrying out conventional surveys in the Chatham Sound area and the Marabell completing Observatory Inlet and continuing with Portland Inlet.

In the western Arctic, CSS Richardson conducted surveys in the Beaufort Sea region from late June until late August, after which it sailed for the Pacific Coast for the quadrennial refit. Severe ice conditions and damage to the ship in ice made it a somewhat unproductive year in the accumulation of hydrographic data. Hydrographers posted on board CCGS Camsell conducted surveys at Paulatuk, Spence Bay and on a circumnavigation of King William Island, including a voyage to Bellot Strait and return. This was the first time that any vessel had circumnavigated King William Island.

In the study of tides, the survey vessel Parry continued its survey of currents on the southern British Columbia coast. The observations taken in 1966 are being used in compiling a current atlas for the waterways between Juan de Fuca and Georgia Straits. A similar current survey is being made in and near the tidal rapids on the northern approaches to the Strait of Georgia. An auto-announcing tide gauge has been installed at Tofino, as part of the tsunami warning system for the Pacific. The gauge can be dialed by telephone and responds with the present tide heights, tendency (rising or falling) and preceding high and low water. If a seismic sea wave is suspected a call to the station will disclose immediately whether abnormal tides are occurring. A new tide station in the western Arctic gauging set was established at Cape Parry and commenced operation in 1966. Extension of the Arctic gauging to Spence Bay, Coppermine and Sachs Harbour is being planned.

CENTRAL REGION

Although the primary activities of the region again consisted of conventional charting, the development of a broadening sphere of research continued. This unit of the Branch assumed responsibility for the Lake Surveillance Program. It undertook hydrographic-automation studies and continued strong support to the hydrographic field training given to 36 new employees.

The trend, started in 1965, of developing highly mobile and flexible operational field charting units, was intensified with the acquisition of additional high-speed sounding craft and portable medium-range electronic positioning equipment. One helicopter was utilized throughout the field season on a time-shared basis by three parties and again provided invaluable assistance.

The charting activities of this region concentrated on waterways used by small boats.

The charting of the Trent-Severn system continued, with surveys being completed from Balsam Lake to Bobcaygeon. Some revisory information was obtained in the areas surveyed in 1965. To date, Small Craft Chart Folio (2028) and a revised edition of Chart 2015 have been published as a result of these surveys. Additional chart folios are in an advanced stage.

The hydrographic survey of Rainy Lake, begun in 1965, was completed during the 1966 field season. The survey of Lake of the Woods was to start in 1967. Lake of the Woods is one of the most popular boating areas in northwestern Ontario and has a summer population of over 100,000.

An urgent program of locating and surveying a small-boat channel from Sorel to the Expo Marina site in Montreal Harbour was completed. The development of this channel, which was buoyed in April 1967, was essential to ensure a safe and orderly flow of pleasure-boat traffic to Expo during centennial year.

A shore-based survey unit, operating from Tobermory, continued surveys in the entrance to Georgian Bay and completed large-scale charting of the southwestern approaches to the bay to facilitate pleasure-boat navigation in that region. During the early months of 1967 this unit also made preparations for a hydrographic survey of the popular but dangerous pleasure-boat route between Port Severn and Parry Sound.

In the early months of 1967, preparations were made for charting Presqu'ile Bay and the approaches to Trenton during that field season. This survey will facilitate production of new charts of the western approaches to the Bay of Quinte and the southern approaches to the Trent-Severn Waterway.

As a part of its additional tasks, the Region seconded three hydrographers to carry out hydrography in the Arctic Archipelago as part of the Polar Continental Shelf Project. Soundings were obtained using submerged transducers towed from aircraft and located with the aid of electronic positioning systems. Early in 1967 the hydrographic team was increased to five experienced hydrographers because of an expanded Arctic charting program.

Hydrographers from this Region also assumed operational responsibility for carrying out the Lake Surveillance Program with the main activities centred in Lake Ontario. The operational base of this unit was Kingston, Ontario, with one chartered ship and an independent sounding launch being used for data collection.

EASTERN REGION

The period of this report, which includes the fourth full year of operation of the Bedford Institute of Oceanography, was a time of continuing progress. An extensive program of hydrographic survey was undertaken, and several oceanographic research projects were carried through to the stage where positive and important results were becoming evident.

CSS Baffin completed the combined hydrographic and geophysical survey of the Tail of the Bank, the portion of the Grand Bank south of 45°N. This required a total of almost 22,000 miles of sounding and was only possible by extensive modifications to the LAMBDA electronic-positioning system which enabled the ship to be accurately positioned up to distances of 500 nautical miles from the station on Sable Island.

CSS Acadia first surveyed Havre Aubert in the Magdalen Islands where extensive changes have been made in recent years. The ship's main project was the continuation of the survey of Hamilton Sound, the sheltered passage inside the Fogo Islands, which is being increasingly used by vessels bound for Botwood, particularly in the winter when it is generally clear of ice.

The main project of CSS Kapuskasing was the completion of the survey of Chaleur Bay and its approaches. The charts resulting from this will be of great value to fishermen and to ships bound for the extensive industrial developments on its coasts. At the end of the season a survey was made of Carousse Bank, off Cape Canso, N. S., to complete the offshore survey of the Scotian Shelf.

CSS Maxwell was used to carry out a variety of small projects. A detailed survey was made of the Lurcher Shoal, off Yarmouth, N. S., to enable the Department of Transport to prepare plans to replace the lightship marking this hazard by a permanent light house. In Newfoundland, surveys were made of Trepassey Harbour, the waterfront at Cornerbrook and wharves in Harbour Grace and Carbonear. On the North Shore of the Gulf of St. Lawrence, surveys were made at Natashquan and in Sept Iles Harbour. Semi-permanent tide gauges were established at Port Cartier, Mingan Harbour, on the North Shore, and at Ellis Bay and Southwest Point on Anticosti Island. At the end of the season surveys were made of Port Bickerton, and the new deep-water wharf at Sydney, N. S., and of the bar in the entrance to Sydney Harbour.

Hydrographers assigned to Department of Transport icebreakers in the eastern Arctic completed the survey of the southern portion of Milne Inlet, the harbour which will be used when the extensive iron-ore deposits in North Baffin Island are developed. Extensive reconnaissance surveys were made in the channels around Bylot Island and in Jones Sound.

Of the oceanographic studies, the following merit special mention.

The investigation of the physical oceanography of the Gulf Stream system between the Grand Banks and the Azores, representing several years' work, has yielded a comprehensive atlas and an important paper presenting a new concept of the current patterns and water-mass transports in this area. Good progress was made on the challenging problems of the mechanism of formation and the rate of production of the deep waters of the western North Atlantic, an undertaking which demands that the observations be made in midwinter. Thus, in early 1966, numerous oceanographic stations, each extending to the bottom and covering virtually all of the Labrador Sea, were occupied by CSS Hudson. In early 1967 the coverage was extended to Irminger Sea and Denmark Strait, but with more comprehensive instrumentation, including an array of 25 current meters and 15 temperature recorders moored by the Hudson in Denmark Strait for 40 days. This cruise was a joint undertaking of physical oceanographers from the National Institute of Oceanography, Woods Hole Oceanographic Institution, and the Bedford Institute of Oceanography. The moored array, using some $125,000 worth of equipment, was provided by WHOI. Despite appalling weather, most of the objectives of the cruise were met, including important new data on the variability of the processes of deep-water formation.

Geophysical surveys were carried out on the southern part of the Grand Banks, the Labrador Coast, Ungava Bay, Davis Strait, Baffin Bay and on a segment of the Mid-Atlantic Ridge. Of outstanding scientific interest was the comprehensive exploration by the Hudson of some 2,500 square miles of the western flank of the Mid-Atlantic Ridge centred at 45°30'N and 28°30'W. A major accomplishment of this cruise was the full utilization of a technique for producing on-the-spot bathymetric, magnetic and gravitational maps of the area, and then using the knowledge thus gained to determine the most interesting and promising places at which to sample the bottom by coring, photography and dredge hauls. This technique was made possible by the now reliable data-logging and -processing system, Geodal, developed by the scientists of the electronic-instrument-research-and-design group in the Institute. The full scientific results must await completion of detailed study of the great mass of samples and data obtained, but already it is apparent that new light will be cast on the processes governing the formation of this great ridge, suspected by many authorities of being the key to many riddles in the geophysical and geological history of the earth.

An intensive study, begun three years ago, on the growth of polar sea ice and on related processes in the sea water beneath is now yielding results. The temperature field as a function of time in a developing ice sheet at Cambridge Bay, Victoria Island, in the Northwest Territories, has been precisely observed and an analysis of the results reported in a recent paper. The process of salt ejection from the ice as it grows and the resultant effects in the sea water below have been studied both in the field and in a

laboratory model. Such work is adding to the fundamental knowledge of our Arctic marine environment upon which the success of future exploitation will depend.

The continuing marine-geological investigation of the continental shelf encompassed a wide variety of projects. Field work extended from the Arctic to the Bay of Fundy and included such major embayments as Hudson Bay and the Gulf of St. Lawrence. Of more than usual interest was the progress made in delineating the sedimentary structures underlying the Scotian Shelf by the study of exposed strata along the continental slope, culminating in the recovery of rock samples bearing significant amounts of hydrocarbons. The samples were in the form of fresh blocks of siltstone torn from outcropping strata of the wall of the canyon known as "The Gully", mostly in the depth range 750 to 1,500 metres, a few miles to the east of Sable Island. Much interest in these results has been shown by firms engaged in oil exploration on the Atlantic Shelves, notably Mobil, which are proceeding to drill on Sable Island.

Policy and Planning Branch

The Policy and Planning Branch was established in January 1967. It succeeded the Resource Development Branch which had been established in April 1965, by the former Department of Northern Affairs and National Resources to co-ordinate federal resource policies; to improve liaison with the provinces on shared resource programs; to conduct broad economic and other studies of resource conservation and development; and to administer certain resource programs.

The Resource Development Branch did not become operative until July 1965, when the various units comprising the Branch were brought together. During 1965 the Branch's efforts were devoted mainly to current work, organization and staff recruitment.

The reorganization of the federal administrative framework for resource management had major implications for the recently formed Branch. Effective January 1, 1966, the Branch was transferred to the former Department of Mines and Technical Surveys. The Branch's advisory, research, planning and interdepartmental and federal-provincial co-ordination functions were transferred with the Branch, as was responsibility for Dominion Lands, offshore minerals below the 60th Parallel and the Roads to Resources Program. The Resource Management Division, however, together with responsibility for resources north of the 60th Parallel, remained with the Department of Northern Affairs and National Resources (now Department of Indian Affairs and Northern Development).

The factors which gave rise to the Resource Development Branch applied equally well to the new Department of Energy, Mines and Resources. These factors included: increased pressure on our resources; technological advances which have made possible large-scale developments often beyond the technical and financial capacity of individual provinces, and often with regional, national or international implications beyond the jurisdiction of the provinces; new concepts of comprehensive, multi-purpose resource development which require a co-ordinated inter-disciplinary and inter-jurisdictional approach in resource policy; new concepts of regional economic development and the establishment of agencies and programs to stimulate growth in less favoured areas, which again require a co-ordinated inter-jurisdictional approach in planning, including co-ordination between regional policies for resources and regional policies in other sectors; and increased emphasis on the economic and social as well as the engineering and technological aspects of resource development. These factors were of particular and growing significance in the field of water resources.

A reorganization study of the Department recognized these factors, and in January 1967, the Resource Development Branch became the nucleus of the Policy and Planning Branch of the Department's Water Group.

On its establishment, the Policy and Planning Branch assumed responsibility for advisory services on water and related resource policies and programs; for interdepartmental and federal-provincial co-ordination and liaison; for basic and applied economic and interdisciplinary research; for departmental, interdepartmental and federal-provincial resource investigations and studies; and for negotiation and administration of joint programs in the water field.

The Branch is organized into three major divisions, together with administrative and personnel support services, as follows:

(1) Policy Co-ordination and Administration: Continuing studies to formulate advice and recommendations on regional and national renewable-resource policies and programs; interdepartmental co-ordination and federal-provincial liaison in the study and implementation of resource policies and programs; liaison between agencies of the federal government and the Canadian Council of Resource Ministers; and negotiation and administration of joint federal-provincial water programs.

(2) Resource Planning: Staff support for water-resource investigations, including comprehensive basin and regional planning studies, undertaken directly by the federal government or through federal-provincial or international agreements; studies of the economic, social, legal and other aspects of regional and national water policies and programs; development and implementation of federal and federal-provincial "systems" for the collection, compilation and processing of certain water data including a water-use inventory.

(3) Resources Research: Research directed towards the best use of the national resources of Canada, through integration of existing knowledge in the economic, sociological, scientific and technological fields; a source of specialized advice to other divisions and branches; administration of a program of grants in aid of university-sponsored research.

It is evident from the above that, during the period covered by this report, a great deal of the effort of this embryo Branch has been expended on preparatory work. Even so, the Branch was able to initiate or participate in a number of programs.

The Branch provides the secretariat for two senior interdepartmental resource committees, viz., the Advisory Committee on Water Use Policy and the Interdepartmental Committee on Resources. It also maintains liaison between federal agencies and the Canadian Council of Resource Ministers.

In support of the Council of Resource Ministers, the Branch co-ordinated federal preparations for the National Conference on Pollution and Our Environment, held in Montreal in November 1966. This important conference produced a large number of guidelines on water, air and soil pollution. In early 1967, the Branch initiated an evaluation of the guidelines relating to water pollution. This led to recommendations for federal action on water pollution, recommendations which were presented to the Council of Resource Ministers for consideration in May 1967.

In November 1966, the Government of the United States invited the Government of Canada along with other nations to participate in an International Conference on Water for Peace to be held in Washington from May 23 to 31, 1967. Following the government's decision to accept this invitation, the Branch assumed responsibility for arranging Canada's participation in the conference. With the full co-operation of the ten provincial governments, a National Committee on the Water for Peace Conference was established. The secretariat for this committee, and for a similar interdepartmental committee, was provided by and through the Branch. Largely as a result of the co-operation achieved through these committees, it was possible to arrange vigorous Canadian participation in the conference in a very short time. Canada's contribution included a country situation paper, over fifty technical papers, a major exhibit and a large and highly qualified delegation of water-resource ministers and experts drawn from both the federal and provincial governments.

Among research projects started by the Branch were studies on pollution, the use of air-photo interpretation for watershed planning, an historical study of federal resource policies, and an examination of the theory of market structures and their implications for resource development.

In addition to the above, the Branch is represented on the Canada-Ontario Co-ordinating Committee for the Northern Ontario Water Studies. It participated in continuing negotiations on the proposed Saskatchewan-Nelson Basin Studies and other similar efforts.

The Branch also co-operated with the Science Secretariat in an inventory and assessment of water-resources research in Canada. The results of this study will be extremely useful to the Branch in the administration of the Department's grants in aid of water-resources research, an example of which is the grants in aid to the University of Manitoba for an interdisciplinary study of western water resources.

Inland Waters Branch

(Note: During the period covered by this report, the Inland Waters Branch did not yet operate as such but rather as two separate branches -- Water Resources and Water Research. The relevant activities are therefore described under these two former headings.)

Water Resources Branch

The Water Resources Branch comprises the Canadian Hydrometric Survey, the Planning, Great Lakes and Research Divisions and Branch administration. The director is a member of the Northern Canada Power Commission. Senior Branch engineers serve as members of numerous federal-provincial and international engineering boards and boards of control.

The Branch carries out systematic hydrometric and sediment surveys throughout Canada, studies and analyzes problems involving waterways of federal-provincial and international concern, compiles a water-power-resource inventory of Canada and administers legislation pertaining to international rivers, water power and water conservation.

THE CANADIAN HYDROMETRIC SURVEY

The Canadian Hydrometric Survey conducts a systematic survey of streamflow, water levels and water-borne sediment throughout Canada, and snow and glacier surveys and water-power surveys, the latter mainly in areas of federal jurisdiction. On rivers subject to dangerous floods, frequent observations of stage are obtained and a flood-warning service is provided during danger periods; on many rivers, a study of river conditions in the upper reaches together with current meteorological data makes possible day-by-day computation of probable flood stages in the lower reaches. Although these activities are designed to meet the requirements of the federal government, an increasing portion of the total effort is aimed at satisfying requests from the provinces.

The Canadian Hydrometric Survey and its predecessors have collected and published basic streamflow and water-level data on a national basis for more than half a century, the sediment survey has been in operation since 1961. These surveys are being expanded steadily and at present are conducted from 27 field offices extending from St. John's, Newfoundland, to Whitehorse, Yukon Territory.

During the fifteen months under review, some 150 stations were added to the gauging network, bringing to approximately 2,000 the total number of streamflow and water-level stations. Sediment data are gathered at 55 of these stations, an increase of 17 stations during the period.

A start has been made on placing all water-level and streamflow data on magnetic tape for rapid retrieval. At the same time, special equipment has been obtained and work initiated on automating the extensive computations which so far were performed manually in the determination of streamflow data.

An Arctic River Work Group has been established to assess the problems of obtaining winter flows in Arctic rivers and to develop special equipment for determining flows under ice cover.

Development of a training program for standardizing field operations across the country was begun and a program to produce an index of all hydrometric and sediment-survey data was initiated in 1966.

An intensive program of sediment surveys on the lower Fraser River was continued to provide a better basis for economic and engineering design of projects associated with the maintenance and improvement of the navigation channels of that river. A similar program is under way on the South Saskatchewan River to determine the effect of sediment deposition behind the Gardiner Dam and the amount of erosion downstream of the dam caused by the release of water which, being relatively sediment-free, will have an affinity for sediment.

PLANNING, GREAT LAKES AND RESEARCH DIVISIONS

The Planning, Great Lakes and Research divisions carry out most of the special studies and engineering investigations for which the Water Resources Branch is responsible. Senior staff members of

these divisions represent the Branch on some 30 engineering boards and committees of an international, federal-provincial or inter-departmental nature.

During the fifteen months under review, conservation projects took up most of the staff's time, followed by Great Lakes-St. Lawrence River studies, hydrologic studies and the International Hydrological Decade program.

In hydraulic and hydrologic studies, computer methods offer the prospect of considerable savings in time. The use of digital computers increased markedly over previous years, permitting a substantial increase in work assignments.

PLANNING DIVISION

More than half the time of all three divisions was used by the Planning Division, due to the number and diversity of its investigations and studies.

The Canada Water Conservation Assistance Act provides a statutory basis for financial assistance to the provinces in the construction of major works for water conservation and/or control. To this end, work was continued in connection with applications for assistance, hydrology studies, checking of structural designs, study and approval of contract documents and inspection of a number of projects being constructed under the Act.

With ratification of the Columbia River Treaty by Canada and the United States, the Columbia River Treaty Permanent Engineering Board was established to ensure that the objectives of the treaty are carried out. The chairman of the Canadian section of the four-man international board is a senior officer of the Division.

Following agreement between Canada and Ontario in 1965, field surveys were initiated in the Planning Division for co-ordinated studies of Ontario's northern water resources and their economic development.

Among several unrelated hydrologic studies undertaken were: the determination of hydrologic zones in the Eastern Rockies; studies of base flow, half flow and water balance in the Marmot Creek Basin; flood study of Nova Scotia.

Assistance was given to the Atlantic Development Board in an investigation of present and potential sources of water supply in relation to present and future demands in the Atlantic Provinces.

An agreement was signed by the governments of Canada, Nova Scotia and New Brunswick for a two-year study of the development of electric power from the tides of the Bay of Fundy and the transmission of that power to markets in Canada and the United States. The Division is represented on the Engineering and Management Committee which, together with the Atlantic Tidal Power Programming Board, was established to carry out the study.

Engineering studies and negotiations with the United States for a treaty covering co-operative development of the Saint John River continued during the period.

GREAT LAKES DIVISION

The Great Lakes Division maintains a regulation and study office in Cornwall, Ontario, which is responsible for Lake Ontario-St. Lawrence River regulation. In addition, the Cornwall office has been responsible for detailed studies relating to the development of new regulation plans for the Great Lakes, and for carrying out a hydrologic study of Lake Ontario.

Officers of the Division in Ottawa took part in studies initiated by the International Great Lakes Levels Board and the Board's working committee in the four principal categories - shore property, navigation, power and regulation. A pilot computer study of Lake Ontario was carried out to develop methods of simulating water inflow to the lake and to establish new regulation procedures. The pilot study has produced mathematical models for simulating inflow to all the Great Lakes. Similarly, various preliminary regulation plans for computer application are being developed for further regulation of the Great Lakes. The Division undertook a number of other projects on behalf of the International Lake Superior Board of Control, International Niagara Board of Control, International Niagara Committee and the Co-ordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data.

The Nelson River Programming Board was assisted in a comprehensive hydro-electric power study of the Nelson River. A start on Phase 1 of a co-operative plan of development has been made, and an agreement with Manitoba, to arrange the details of federal participation, is being negotiated.

Assistance was given in connection with Stage 2 of a study by a federal-provincial working committee of the problems associated with long-distance power transmission, with particular reference to the physical and economic possibilities of establishing a national power grid.

Liaison with other federal and provincial agencies on the Interdepartmental Committee on Energy Statistics continued with a view to resolving common problems inherent in the collection and use of energy statistics.

RESEARCH DIVISION

The principal function of the Research Division is the Canadian contribution to the International Hydrologic Decade, an ambitious ten-year program of investigation shared by more than fifty nations and designed to fill many of the gaps in man's knowledge of water.

Canada, with a wide range of hydrologic environments, is in a unique position to contribute to world knowledge in this field. Some 169 projects involving a variety of subjects are being sponsored co-operatively in Canada by federal and provincial agencies and by universities.

The role of the secretariat, which is part of the Research Division, is mainly administrative. Its work consists chiefly in the preparation of minutes of Canadian National Committee meetings, liaison with provincial committees, preparation of reports for national and international distribution, and the carrying out of national surveys on subjects within the Decade's field of interest. The secretariat helped to arrange lecture tours for foreign specialists in Canada. The semi-annual "News Bulletin", containing highlights of Canadian activities in the Decade program, was published and distributed by the secretariat; and assistance was given in the organization of national and regional seminars.

A schedule for a series of workshop and familiarization seminars was established in 1965. These sessions commenced in January 1966 with a workshop seminar on "Research Basin Studies" held in Ottawa. Regional workshop seminars on the same topic were held in Calgary and Toronto in April. The fourth workshop seminar on "Ice Formation and Breakup in Lakes and Rivers" was held in Quebec City in November. The first familiarization seminar on "Principles of Hydrology" was held in September at the University of Saskatchewan. It offered scientists trained in the various disciplines associated with hydrology the opportunity to gain a better understanding of the full science of hydrology.

Water Research Branch

The Water Research Branch was created from units in the Department of Mines and Technical Surveys on September 7, 1965. The four pre-existing units of the Department brought together to form the Branch are:

Groundwater Section (from Geological Survey),
Industrial Waters Section (from Mines Branch),
Glaciology Section (from Geographical Branch),
Tides and Water Levels Section (from Marine Sciences Branch).

In addition a new unit was formed to conduct limnology research in the Great Lakes.

The purpose of the Water Research Branch is to add to the knowledge of Canada's water resources and to contribute to the understanding of the hydrologic sciences. Due to the stimulation of programs by the International Hydrologic Decade and the increased tasks in water pollution abatement assigned to the Department, the research and survey programs of the pre-existing units were revised and expanded. Almost all of the Department's I.H.D. work was concentrated in this Branch.

The increase in water studies and the consequent reorganization introduced major problems of recruitment in a field of scarce manpower supply, and of acquiring space for new facilities both in Ottawa and in regional laboratories and offices. Some of the latter problems were partially solved by concentrating much of the Branch in new quarters in No. 8 Temporary Building, in July 1966. Later in the year, planning proceeded for integration of the Water Research Branch with the Water Resources Branch, to allow all inland water survey and research work to be conducted within one branch.

HYDROLOGY DIVISION

The principal function of the Hydrology Division is research in hydrogeology and glaciology. In addition, advice is provided to other government agencies on water management and supply problems. The Division's program includes much of the Department's contribution to the International Hydrologic Decade. It has 25 I.H.D. projects in progress and participates in nine others with federal or provincial agencies.

The Groundwater Section continued its hydrogeological research and basin studies in different hydrogeological regions of Canada, in order to provide knowledge of Canada's groundwater resources. Most of this work is also in support of Canada's I.H.D. commitments.

The national observation-well program was expanded and a number of experimental observation wells were installed. A computer-operated system is being designed for storage, retrieval and processing of the data from the observation-well network as well as from other studies.

In British Columbia, representative basin studies were carried out in the Fraser Lowland and in the southern Interior Plateau.

In the Prairie region a number of studies were continued to add to the knowledge of groundwater-flow systems and groundwater chemistry. Representative basin studies were continued at Good Spirit Lake, Saskatchewan, and Oak River, Manitoba. Investigations of the influence of Lake Saskatchewan on aquifers in the upper Cretaceous bedrock continued. Mass-transfer studies and a study of the hydrochemical interpretation of groundwater flow were carried out in the Moose Mountain area, Saskatchewan. A palaeohydrological study of the three Prairie Provinces collected over 800 ostracod specimens to be used in assessing the past changes in Prairie hydrology as an aid in predicting future ones. A water-balance study of a mountain bog was started in the Kananaskis wetland.

All these Prairie studies have contributed to the knowledge of groundwater flow and have provided field data for computer simulation of groundwater-flow systems, as well as much new information on the important part played by Prairie sloughs in the overall hydrology of the area.

In Ontario, near Iroquois Falls, the hydrogeology of a forested basin is being studied to obtain information on the hydrogeology of unproductive wetland areas as found in a large clay plain.

In the Maritimes area a hydrogeological study was conducted within the North Nashwaaksis basin in co-operation with New Brunswick agencies, and a preliminary water balance was established to assist with provincial snow-melt studies. On Prince Edward Island further instruments were installed for studying the salt water-fresh water relations along the coast. This knowledge will be useful in fully developing the groundwater resources of the island.

The Groundwater Section also advised other federal government agencies on water supply problems, provided consultation and advice to ARDA and ADB on major water investigations, and contributed papers to the National Conference on Pollution and our Environment, and the International Conference on Water for Peace.

The Glaciology Section conducts research on Canadian glaciers to increase our understanding of how they function and how they relate to other parts of the hydrologic cycle. At present the work consists chiefly in the collection of data for office studies and the measurement of the mass balance -- or the annual increase or decrease in mass -- of five glaciers in an east-west profile across the southern Cordillera. The material will serve as a background for future scientific studies.

The studies of the five glaciers -- as against three glaciers in the preceding year -- are part of an international network of glacier studies extending from South America to Alaska, and being done as part of the International Hydrologic Decade program.

Another I.H.D. commitment is compilation of an inventory of Canadian glaciers, and the first part of this task is to determine the distribution and area of glaciers in Canada. The area has been calculated to be 204,000 square kilometres (78,000 square miles); distribution is being compiled. Planning is under way for the more complex problem of a continuing inventory providing quantitative results related to chronological changes.

The Section co-operated with the Geographical Branch in measurements at Decade Glacier on Baffin Island and made a field survey of the Per Ardua Glacier on Ellesmere Island in co-operation with the Defence Research Board.

GREAT LAKES RESEARCH DIVISION

The Great Lakes Research Division was organized during the year for carrying out comprehensive research to increase knowledge of the physical, chemical and geological processes acting in or affecting the Great Lakes: especially water circulation, composition and temperature; the distribution and assimilation of pollutants; the reactions at the air-water interface; and the relations between the water and the shore and bottom materials.

Such knowledge will greatly increase the Department's ability to provide data and advice in support of the International Joint Commission Reference on pollution in the lower Great Lakes, as well as to the Ontario agencies concerned with pollution abatement, to industries and others.

The physical and chemical limnology program was oceanographically oriented and was substantially planned and staffed by person-

nel from the Marine Sciences Branch. M/V Brandal was fitted out as a research ship in Halifax, then brought to the field base at Kingston where the necessary shore facilities were established in co-operation with the Department of National Health and Welfare. The latter participated in the field studies by conducting bacteriological measurements and sharing in the chemical measurement program. M/V Brandal made 18 one-week cruises in Lake Ontario and 1 one-week cruise in Lake Erie to gather data for studies of chemical balance, heat exchange, thermal structures and circulation. The approximately 54,000 pieces of serial data collected were processed in co-operation with the Canadian Oceanographic Data Centre.

During the winter, analysis of the data was started and planning for future research was continued. This involved the development of instrumented research towers and anchored buoys as well as many other specialized instruments for use from the ships.

The limnogeological work embraces geological, geochemical, geophysical and biological-palaeontological investigations of the sedimentary processes occurring within the Great Lakes, and their bearing on pollution. Sediment sampling and seismic-reflection profiling were carried out in Lake Ontario in co-operation with the Geological Survey of Canada and provided a regional reconnaissance of bottom conditions and sediment distribution throughout the lake. The nature and general distribution of the materials on the lake bottom were delineated as well as the principal areas of thick unconsolidated deposits underlying the lake bottom.

During the winter, laboratory investigations were started of various physical properties of the samples from Lake Ontario, utilizing standard techniques available in the Geological Survey sedimentological laboratory. A start was also made in developing rapid analyses using specialized instruments and in setting up a biogeochemical laboratory to investigate the biological constituents of lake-bottom sediments.

In co-operation with the Ships Division, Marine Sciences Branch, two major research vessels were planned and a contract let for the construction of one of them.

An engineering section began preparation of suitable machine and electronics shops to provide the equipment and instruments required by the ships, research towers and anchored buoys. Considerable time was spent in planning the new Canada Centre for Inland Waters to be constructed at Burlington, Ontario, including temporary facilities to allow operations to proceed at this centre during construction of permanent facilities.

WATER QUALITY DIVISION

The Water Quality Division does basic and applied research on water quality in its broadest sense. This includes studies on the quality of Canadian surface waters, and research on treatment methods for improving water quality for industrial and municipal use and for pollution abatement. Also included is research into corrosion prevention and treatment of industrial waste water. The Division's laboratories provide water analyses to a wide variety of users and conduct research into analytical methodology.

As a part of its commitment to the International Hydrologic Decade, the water-quality network was expanded from 60 sampling stations to 140 sampling stations, on 125 rivers. In addition, the Division is co-operating with provincial and federal agencies and universities in I.H.D. studies on four research basins and planning similar work on four additional ones.

The Division continued to assist the Departments of National Defence and Public Works on boiler-water treatment and to provide technical assistance to provincial, and other public and private agencies on water quality and treatment. A water-corrosion study in co-operation with National Association of Corrosion Engineers was completed. Research on methods of analysis was continued in connection with the American Society for Testing Materials, B-19, and in co-operation with the U.S. Department of Health, Analytical Reference Service, National Centre for Urban and Industrial Health.

Co-operative studies were carried on with the Federal Department of Fisheries and the New Brunswick Department of Natural Resources on pollution in the mining area of northeastern New Brunswick. Recommendations were made to the Atlantic Regional Advisory Committee of the Atlantic Development Board on a number of problems relating to abating pollution from toxic heavy metals.

In western Canada the long-term survey of water quality continued for the International Joint Commission and assistance was provided to the Eastern Slopes (Alberta) Watershed Research program on problems concerning water from coal mines entering the headwaters of the Saskatchewan River system.

Difficulties were encountered in recruiting for the expanded work because of lack of qualified personnel and lack of suitable space. In Ottawa, quarters were being renovated on Spencer Street and interim arrangements made for staff in other temporary quarters. The eastern regional laboratory commenced operations at the Bedford Institute of Oceanography in Dartmouth while laboratory space was being prepared in Moncton. The western regional laboratory started work in a complex of four trailers at the site of the new Geological Survey building in Calgary, while awaiting preparation of rental quarters. Considerable effort was expended in planning for the future accommodation of much of this division in the Canada Centre for Inland Waters at Burlington, Ontario, and arrangements were made to transfer the trailer complex from Calgary to allow water-quality operations to start at Burlington in the following year. The introduction of automatic analyzers allowed the Division to increase its water analyses in response to the greatly increased demands and I.H.D. requests.

Plans were carried forward for computer storage, retrieval and print-out of analytical data. The programming is being designed to be compatible with requirements of other divisions in the branch and where possible with developing provincial systems.

TIDES AND WATER LEVELS SECTION

The objectives of this Section are to maintain continuous records of water levels in Canada's coastal waters and the navigable waterways of the St. Lawrence River and Great Lakes. From these records, water-level, tidal and current tables are prepared and distributed as quickly as possible. In addition, tidal predictions are provided and research and development undertaken to improve methods of collecting and analyzing data.

After several years' preparation the first completely "made-in-Canada" set of Canadian Tide and Current Tables was issued during the fall. Tidal values for the first time are now predicted on large scale in Canada, and the tables are compiled and printed with the use of computer techniques. Similar techniques are used in presenting the gauging data for the Great Lakes - St. Lawrence River system. Many agencies in and outside of Canada are now requesting these data in the computer-usable format developed by this Section. The tsunami warning centre at Honolulu is provided with up-to-the-minute tidal values from the Tofino Gauging Station on Vancouver Island. The automatic telephone and radio-announcing devices installed at the Tofino Gauging Station and tidal and current-measuring equipment used by hydrographic field parties were exhibited on board CSS Baffin during a visit to Monaco in conjunction with the 9th International Hydrographic Conference, in the spring of 1967. Several papers presented by the Canadian delegation constituted the major contribution on tidal problems during the concurrent Symposium on Tides.

Special tidal surveys were carried out between Quebec City and Father Point to provide data for physical and mathematical model studies of this section of the St. Lawrence River.

New punch paper-tape gauges developed for tidal measurements were installed to further automate the data processing. In addition, these gauges lent themselves with some slight modifications for *in situ* recordings, and two experimental gauges were laid in the middle of the St. Lawrence River.

To reduce the space required for storage of original records of past data, microfilming has been undertaken and is nearing completion.

CANADA

Department of ENERGY, MINES AND RESOURCES

annual report 1967-68

Hon. J. J. Greene, Minister

CANADA

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Hon. J. J. Greene, Minister

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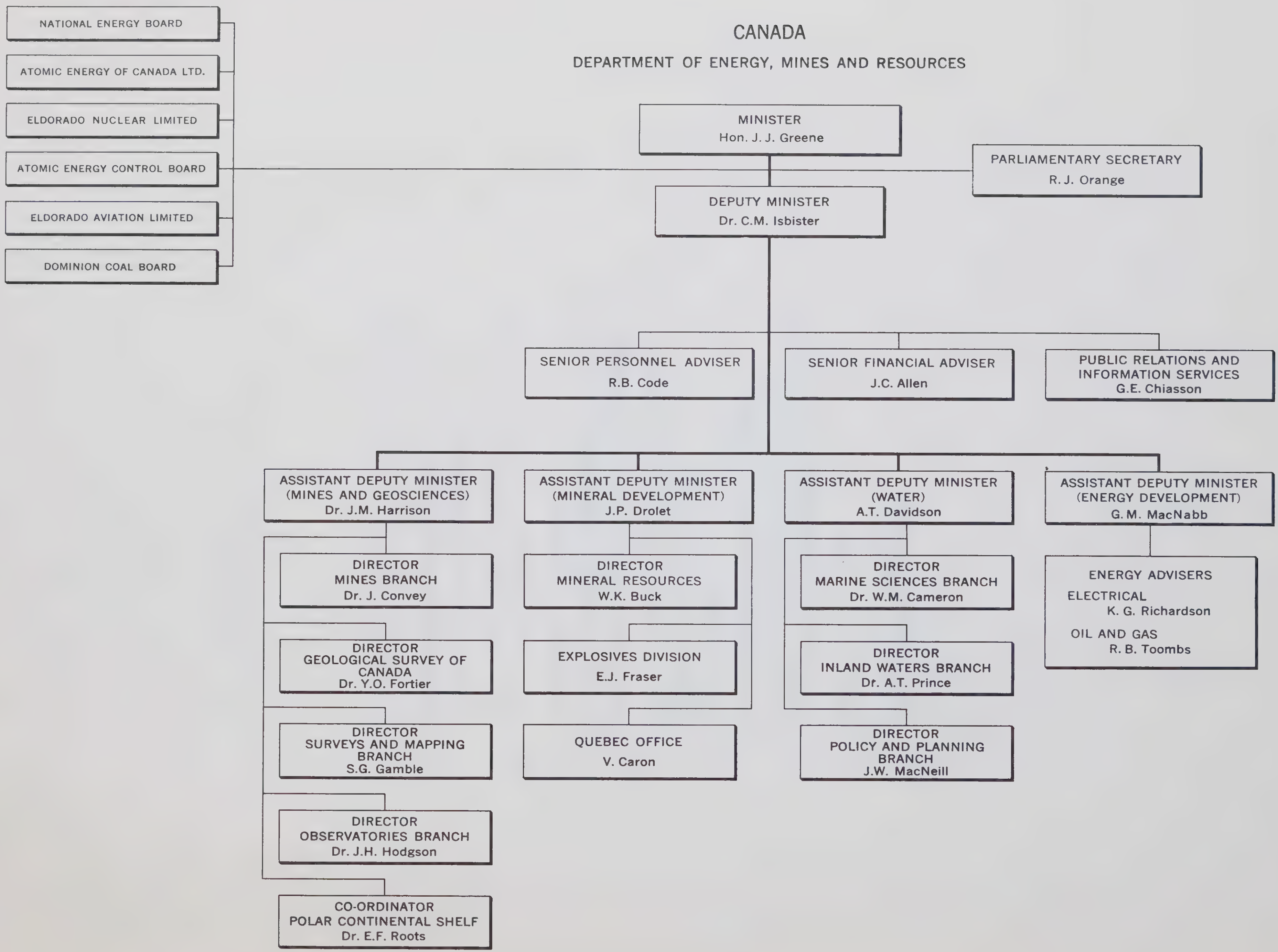

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INTRODUCTION

The Department of Energy, Mines and Resources is the federal government's principal agency for the discovery, investigation, development, and conservation of the nation's mineral, water and energy resources. It carries out geological, hydrographic, oceanographic, geophysical, hydrologic, geodetic, and topographical surveys, engages in mineral and metallurgical research, both technological and economic; assesses and helps to plan the distribution of water and energy resources; and carries out a number of administrative and advisory tasks affecting Canada's resources and the industries associated with them.

The Department is housed mainly in Ottawa, with several research establishments in other parts of Canada. It has a staff of about 5,000 and an annual budget of approximately $114 million.

This report on the Department's operations is the first to cover a complete fiscal year rather than a calendar year, that is, from April 1967 to March 1968, inclusive. It is also the first report period during which the major units of the Department functioned according to the reorganization and expansion initiated in 1966. Noteworthy in this respect is the consolidation and expansion of water research in the Inland Waters Branch, the further development of a Water Policy and Planning Branch, and the organization of the Energy Development Group which in 1967-68 participated in a number of key studies and policy developments.

The programs of the Mines and Geosciences Group, are basic to many aspects of industrial growth and endeavour; and in 1967-68 the demands for information and services in this field reached new levels. The Surveys and Mapping Branch achieved a higher mapping output than in previous years, a gratifying advance due almost entirely to the introduction of new techniques and equipment, without an increase in personnel. Another important achievement was the completion of the topography for the 1:250,000 mapping of Canada. The Geological Survey of Canada sent out 99 full-time field parties and carried out two large helicopter-supported reconnaissance projects. Responding to the needs of the mineral industry, two new divisions were organized within the Mines Branch – a Fuels Research Centre and a Mining Research Centre. The scientists and technicians staffing these divisions concentrate especially on rock mechanics and operations control, on the one hand, and the processing of Canadian fossil fuels on the other.

The Observatories Branch further improved its time service: international timekeeping is now so exact that at current rates the atomic clocks at Ottawa and Washington would drift apart only by one thousandth of a second in the next forty years. The branch's geophysical observations were again expanded.

The Mineral Development Group, whose backbone is the Mineral Resources Division, played an important role in advising on and evaluating Canada's position in the Kennedy Round of negotiations under the General Agreement on Tariffs and Trade (GATT), which concluded in Geneva in June 1967. It also participated in many other reviews and formulations of mineral policy. The Resource Administration Division (during the review period still a part of the Mineral Resources Division) continued to review and grant exploration permits for Canada's offshore areas in the Atlantic, Pacific, and Hudson Bay, and held about $15 million in guaranty deposits in March 1968. Some 40 per cent of Canada's continental shelf area is now under exploration permits.

Of paramount importance in 1967-68 were the department's water programs and the abatement of water pollution.

Three new survey vessels were commissioned by the Marine Sciences Branch of the Department's Water Group, and another ship was readied for pollution studies on the Great Lakes. The Bedford Institute was being expanded. The Inland Waters Branch made a start in establishing the Canada Centre for Inland Waters at Burlington, Ont., by setting up a 25,000-square-foot trailer complex housing officers and research facilities. The Department will co-ordinate the research carried out at the Centre, in collaboration with other government agencies, universities, and private industry. The Policy and Planning Branch evaluated and elaborated the guidelines on pollution control promulgated by the Conference on Pollution and Our Environment, and helped to shape government water policy in other ways.

In Energy Development, officials participated in reviewing prospective Maritime and Newfoundland power developments, progress of the Atlantic Tidal Power Study, the Trans-Canada Grid Study, and several other regional and national ventures in producing and transmitting electrical energy. The Group also participated in studies of Canada's energy fuels – oil, gas, coal, and uranium.

MINES AND GEOSCIENCES GROUP

Surveys and Mapping Branch

The past fiscal year has seen substantial achievement. The output of all divisions was higher than in previous years, a fact that is borne out in more detail in the reports which follow. This increase in production was due almost entirely to the introduction of new equipment and techniques, personnel strength being essentially the same as the previous year.

The Geodetic Survey continued to extend and strengthen the national survey framework. The investigation of minute movements in the earth's crust continued, and a number of deep bench marks (some extending to 90 feet) were established to ensure that the markers would not be subject to the influence of surface changes such as frost effect. The Topographical Survey continued to use the aerodist for establishing horizontal control in wilderness areas and more conventional techniques to increase the density of the Geodetic network in other parts of Canada. The topography of 1:250,000 coverage of Canada was completed during the past fiscal year, except for three small islands in Hudson Bay which will be mapped as soon as control is secured by the Hydrographic Service.

The Legal Surveys and Aeronautical Charts Division continued the delineation and recording of Crown Canada Lands for their orderly and efficient use. In aeronautical charting four new types of charts were produced, and two existing series were extended to improve coverage. In map and chart printing, a new record of 31 million impressions was set during the past year. This increase of 6 million impressions over the previous high was made necessary by the heavy increase in both new map and chart production and the revision and reprint load.

The Interdepartmental Committee on Air Surveys carried out air photography in all provinces and both territories to meet requirements of ten federal departments. An increase in the use of colour photography by scientists and engineers was apparent. A new set of specifications for contract aerial photography was written and distributed during the year.

The Branch continued to provide technical advice to the External Aid Office in connection with control surveys and mapping projects carried out under the Canadian Technical Assistance Program as well as practical training connected with the same program. Senior Branch officials represented Canada at the Commonwealth Survey Officers Conference in London and at the International Union of Geodesy and Geophysics in Switzerland.

The annual meeting of federal and provincial survey directors was held in Fredericton, New Brunswick. The Branch sponsored two international conferences. The first was part of Canada's activity in the Pan American Institute of Geography and History, and brought approximately 40 experts from Latin America to Ottawa to study problems in regional and urban development with their Canadian counterparts. The second international meeting was in cooperation with the Canadian Institute of Surveying and the International Society of Photogrammetry. About 200 experts gathered in Ottawa to study advances in photo-mapping.

In the field of research, investigations into automated mapping systems continued sufficiently to crystallize the Branch's policy on the establishment of a pilot assembly line for the production of topographic maps. The new section, charged with program coordination, was established during the year under review. It has developed computer programs to control inventory, indicate reprint needs and plan revisions. In the years to come this section will be vital to all Branch planning.

Toward the end of the fiscal year the Branch made preparations to absorb the Toponymy Division, the Thematic Map Section and the Map Library from the Geographical Branch which was being dissolved.

GEODETIC SURVEY

Twenty field parties established horizontal and vertical control to extend or increase the density of the existing national survey framework for mapping and charting, municipal control and major engineering projects. In addition the Geodetic Survey continued and expanded several investigational projects.

The extension and strengthening of first-order horizontal control was carried out in the Northwest Territories and six provinces. In the Northwest Territories, Manitoba and Saskatchewan, scale control was provided in existing networks; in the Northwest Territories from Dubawnt Lake to the Hudson Bay, also from Whitefish Lake (latitude 63°) to a point 60 miles north of Lac La Ronge in Saskatchewan. Three map-control points were established at Lynn Lake, Manitoba, for the Mapping and Charting Establishment. In British Columbia municipal control was established in the Greater Vancouver and Victoria areas. A loop from Trail to Creston via Proctor on Kootenay Lake was completed. In Saskatchewan scale control was completed in the Hague-Fife Lake net. In Southern Ontario a number of new stations for municipal control were established and a number of destroyed stations were re-established. In Northern Quebec horizontal control was extended from Richmond Gulf to Great Whale River. Ten stations of a triangulation network across Robeson Channel, N.W.T., were established to provide a control net for future studies on possible crustal movement between Ellesmere Island and Greenland. A local control net was established in the Port Hawkesbury, N.S., area. The Geodetic Survey co-operated again this year with the Topographical Survey in the establishment of a first-order aerodist network north from Lake Nipigon-Kenora and extending west to the Brandon-Dauphin triangulation net in Manitoba.

First-order levelling was carried out in the Northwest Territories and six provinces. In the Northwest Territories the line from Hay River to Fort Smith was completed, closing a 1,400-mile loop. A new line was completed between McMurray and Edmonton with a connection to Smith. In British Columbia the line from Prince George to Hudson Hope and an old line from Matsqui to Vancouver were re-levelled. A new line was levelled along the shore of the Peace River from Bennett Dam to Finlay Forks. In Saskatchewan the Geodetic Survey, in co-operation with the Topographical Survey and the Saskatchewan Survey Office, completed a new line between Lumsden and Fort Qu'Appelle. A winter levelling party completed 115 miles of levelling between Warrens Landing and Cross Lake in Northern Manitoba. In Ontario the line between Toronto and Kingston was re-levelled and a new line was run from Ottawa to Plantagenet. All connections to National Capital Commission monuments in the Ottawa-Hull area were completed. A new line between Amos and Mattagami in the Province of Quebec was completed. An inspection party checked 1,042 bench marks in southeastern Quebec. A number of deep bench marks were established between Toronto and Trois-Rivières – a new program started during this fiscal

year. In New Brunswick two new lines, from Bathurst to Newcastle via Caraquet and from Shediac to Sackville via Cape Tormentine, were completed. Demonstrations with the equipment for establishing deep bench marks were given for U.S. survey agencies.

Four astronomic parties worked in the Yukon Territories and four provinces. In the Yukon, a precise astronomic position for the U.S. Secor station at Whitehorse was determined, including azimuth observations. In British Columbia, 30 deflection stations and three Laplace stations were established in the Vancouver area, the Okanagan and Kootenays. Three Laplace stations were established in Alberta and a precise astronomic position was determined for the U.S. Secor station at Lynn Lake, Manitoba. Two Laplace stations and one deflection station were established in northern Quebec. A consolidated up-to-date list of astro-geodetic deflections of the vertical was prepared for the 14th General Assembly of the International Association of Geodesy in Lucerne, Switzerland.

A Research and Development group was set up last fall. Among other activities, a start was made on a long-range program to determine geoidal cross-sections and contours in Canada. New electronic-computer programs were developed for processing and analysis of data. The levelling section carried out preliminary tests with laser equipment. In the laboratory the usual maintenance and checking of all divisional electronic and radio equipment was performed and courses in electronic distance-measuring equipment were given to personnel in and outside our division.

The staff members again attended a number of national and international meetings and symposia. One member attended the Conference of Commonwealth Survey Officers held at Cambridge, England, and three members attended the 14th General Assembly of the International Association of Geodesy, as part of the International Union of Geodesy and Geophysics Meetings, in Lucerne, Switzerland.

TOPOGRAPHICAL SURVEY

In this year, the Topographical Survey experienced a high rate of production in new mapping and a heavy demand for special products. One highlight of the year was the virtual completion of the 1:250,000 series of maps for all of Canada; several islands in Hudson Strait remain to be mapped at this scale but bad ice conditions there in 1967 prevented necessary surveys. With emphasis on the 1:250,000 mapping thus reduced, it was possible to concentrate more effectively on 1:50,000 mapping, and the production rate at this scale was almost doubled. Mapping cleared for reproduction remained at about the normal level and consisted of 26 maps at the 1:25,000 scale, 418 at the 1:50,000 scale and 23 at the 1:250,000 scale, representing areas of 1,160, 76,500 and 117,000 square miles respectively. Included with the 1:50,000 mapping are 74 maps compiled previously by the Mapping and Charting Establishment, Department of National Defence, and transferred to this Division for editing.

Under the agreement whereby this Department prints the 1:50,000 mapping produced by the British Columbia Department of Lands, Forests and Water Resources, the Topographical Survey accepted 36 map sheets for review prior to clearing to Map Compilation and Reproduction for publication.

At the request of the Observatories Branch, the Topographical Survey embarked on a long-term program of blanketing the western mountainous regions of Canada with reliable height data required for gravity studies. Accurate positioning of the control points is inherent in the program, and the accumulated data will greatly assist future detailed and revision mapping. It is expected that provincial and Defence Department support will speed the effort.

Field Surveys. The Geodetic and Topographical Surveys again collaborated in using the aerodist system of trilateration to extend first-order geodetic control into northwestern Ontario and southern Manitoba, establishing 26 new positions. This operation included 6,000 line miles of aerodist-controlled photography required for 1:50,000 mapping control of 105,000 square miles of immediate interest to the Inland Waters Branch.

In 15 days in September, the aerodist system was used to correlate eight Geodetic Survey positions around the Gulf of St. Lawrence to provide control for hydrographic surveys. Aerodist-controlled photography was obtained for revision mapping of a major part of Anticosti Island.

The tellurometer traversing and trigonometric levelling, a basic requirement for the gravity program mentioned earlier, covered 27,500 square miles in southern British Columbia with about 300 control points, and incorporated positions established by provincial and other surveys.

Another air-supported operation assigned to a Mapping and Charting Establishment field party obtained control for detailed mapping of 24,500 square miles around Ross River, Y.T., where important mining and prospecting development is taking place. This party also made observations on the Steele Glacier to make possible a new plot of its progress.

For several years, the Department has been assisting municipalities and other local bodies to establish co-ordinate systems of control surveys. Spirit levelling became an important part of this service in 1967. Six field parties undertook surveys of this nature in the Canso Strait area, Liverpool and Lawrencetown in Nova Scotia; Ottawa, Niagara Falls, St. Catharines, Welland, Barrie, Orillia, Kitchener, Waterloo, Brantford and London, and for the Department of Highways, in Ontario; Grande Prairie in Alberta; and Vancouver, B.C. Reconnaissance for the following year's work has become an accepted part of these assignments.

The Division continued the service of issuing notification lists and distributing advance information prints of new mapping. The latter amounted to over 1,000 prints per month.

Air Surveys. Work on the 1:250,000 series of National Topographic Series maps consisted of clearing the last 30 sheets through the final stages of compilation. With this mapping virtually completed, it was possible to use staff and plotting instruments more effectively, and this has resulted in a marked increase in production of 1:50,000 mapping. Modern equipment and new procedures are greatly assisting progress toward more economical production of detailed mapping and revision of older mapping. Work began on revision of the 1:25,000 map series in Vancouver and Calgary.

There was a continuing demand for special mapping, ranging in size from a simple plot taking one day to mapping 5,400 square miles of the Slave River lowlands for the Department of Agriculture, a project that required several months. Most of these requests came from other branches within the Department, particularly Marine Sciences and Inland Waters. Photomaps and controlled mosaics, introduced in 1967 as map substitutes, proved very popular with all users of specialized maps and accounted for about one-half of the 80 individual or group projects undertaken.

LEGAL SURVEYS AND AERONAUTICAL CHARTS

Legal surveys in Indian Reserves, national parks and the territories were carried out as usual. Of particular interest is the large modern subdivision undertaken at Morphy, west of Yellowknife, as a new settlement for the Indians presently located at Fort Rae.

Sixteen field parties were engaged on legal surveys in the public lands of Canada. In addition, contracts were arranged with 23 private survey firms for government surveys, and technical instructions were issued for 167 surveys on Crown Canada Lands for private and provincial agencies. Surveys on 73 Indian Reserves accounted for the major part of the field work. The survey of six new historic sites in the Maritimes and lot and parcel surveys in Banff and Jasper townsites completed the work in the provinces. In the territories, establishment of local control networks for legal surveys was continued with new ones established for the Yellowknife and Carcross areas and extensions made to those at Vangorda Creek and Ross River. Subdivision surveys were carried out at Eskimo Point, Rankin Inlet, Dawson Landing, Fort Simpson, and Pine Point in the Northwest Territories, and at Ross River and Whitehorse in the Yukon. Photo control for the extension of large-scale mapping was established at Eskimo Point, Rankin Inlet, Baker Lake, Fort Resolution, Fort Simpson, and Fort Smith.

Two commissions for interprovincial and territorial boundaries were active in the period from April 1, 1967. The survey of the north boundary of British Columbia was ratified by Parliament. The resurvey of the southerly 240 miles of the Manitoba-Saskatchewan boundary was begun and approximately 100 miles of trial-line survey were completed.

Survey documents entered in the Canada Lands Surveys Records numbered 631 plans and 216 field books. About 53,200 document extracts, publications and astronomical field tables were dispatched, and information on 2,294 airline distances was provided for official purposes.

In aeronautical charting four new kinds of charts were produced, and two existing series were extended to improve coverage. An aeronautical chart at the scale of 1:1,000,000, designed to meet the needs of civil and military visual air navigation, was produced to test its national and international suitability. An air-facilities-planning chart of the province of Saskatchewan was produced at provincial request, and an information chart was developed and produced for passengers on Department of Transport aircraft.

The Board of Examiners for Dominion Land Surveyors met ten times. Six centres were selected for the 1968 annual examinations. Of the 30 candidates examined three passed their preliminaries, five their intermediates, and five qualified for the Dominion Land Surveyor commission.

INTERNATIONAL BOUNDARY COMMISSION

The International Boundary Commission continued the joint annual maintenance required for the effective definition and marking of the boundary between Canada and the United States. Inspections were carried out on various parts of the line, and three Canadian field parties completed maintenance on five sections.

The Commissioners for Canada and the United States made joint inspections of conditions along the boundary, including the work of field parties completing maintenance on various sections of the line from New Brunswick westward to Saskatchewan.

The three Canadian field parties completed the following maintenance operations:

1) On the New Brunswick-Maine boundary: 34 miles of 20-foot-wide vista were treated with herbicides to retard undesirable growth. One hundred and eleven monuments were inspected, and five were repaired.
2) On the Highlands section of boundary between Quebec and Maine, 19 miles of 20-foot-wide vista were recleared and stump treated with herbicides, 494 monuments were inspected, seven monuments repaired, and one ornamental monument established.
3) On the 45th-parallel section of the boundary, between Quebec and Vermont, distance measurements were made by geodimeter between monuments along 23 miles of the line. Fifty-four monuments were inspected during the course of the geodimeter work.
4) In the Great Lakes district the positions of buoys marking the line through western Lake Erie were checked; observations were made to improve the location of five control stations along the Detroit River and one reference monument on the St. Clair River.
5) An aerial application of herbicides was made to retard undesirable growth on an 80-mile section of boundary in the Kootenay district of British Columbia.

Altogether, Canadian parties recleared 19 miles of boundary vista, treated 133 miles of vista with herbicides, measures 23 miles of line with geodimeter, inspected 659 monuments of which 12 were repaired, and located 10 boundary monuments and markers.

MAP COMPILATION AND REPRODUCTION

Map and chart production for the year was slightly higher than for the previous year.

Maps received from the Topographical Survey for reproduction numbered 288. These included 30 at the scale of 1:25,000; 229 at 1:50,000; and 29 at 1:250,000.

Maps received from the Mapping and Charting Establishment for plating and printing numbered 62. These included 2 at 1:25,000; 47 at 1:50,000; and 13 at 1:250,000.

Maps and charts printed numbered 4,455. Of the total, 2,060 were printed on the large offset presses and 2,395 on multilith.

In the spring of 1967, the status of the 1:50,000 series stood at 28.9 per cent published for 6,304 sheets of a potential 21,814. The status of the 1:250,000 series stood at 88.9 per cent published, or 878 of a potential 918.

The conversion of the eight-mile series to 1:500,000 was 86.8 per cent complete, with 191 maps.

Thematic Mapping Unit. With the dissolution of the Geographical Branch, various divisions of that branch were transferred to other parts of the department. The Division of Regional Geography was incorporated within the Map Compilation and Reproduction Division and renamed the Thematic Mapping Unit. The following is a summary of that unit's work during the past fiscal year.

Multi-color maps: A map, entitled *Territorial Evolution of Canada* and published in English and French, showed the growth of Canadian territory and boundary changes from 1667 to 1949. Another map was entitled *Atlantic Provinces and Economic Activity.* A composite of seven maps showing the economic geography of the Atlantic provinces was produced for the Atlantic Provinces Economic Council.

Urban Analysis Series: A number of maps of Toronto showed density of buildings, land slope and elevation, and broadcasting facilities. These maps were prepared for the Emergency Measures Organization. Another series of maps portrays soil types and elevator services in a region of Saskatchewan.

Work continued on the desk atlas of Canada. In the Urban Analysis Series, research and field work were completed for 22 maps of Montreal. Cartographic work continued on 15 maps of Toronto and 21 maps of Montreal.

Research and cartographic processing were done on a revised edition of the Natural Resources Map of Canada.

AIR-PHOTO AND MAP DISTRIBUTION AND CIRCULATION

National Air Photo Library. During the period under review, 6,620 requisitions for photographic work, the highest annual total in the Library's history, were prepared for processing. These requisitions covered 711,905 reprints from federal government air-survey negatives (contact prints, enlargements, multiplex diapositives, mosaics, lantern slides, etc.).

The Library received 97,385 new photos, bringing the total of the Library collection to well over three million.

In addition to the air-photo requirements of the various federal government departments, the Library fulfilled requests from provincial government departments, municipalities, exploration and development companies, educational institutions, religious groups, publishing firms, professional societies, and private individuals.

Twenty-five thousand copies of a new pamphlet *How to order air photos* were distributed, and a further 15,000 copies were ordered for future distribution.

Progress continued on the program to copy, on 70-mm film, some 800,000 prints from nitrate-base negatives. Over 200,000 prints have been copied to date. The purpose is to preserve this pictorial history of Canada accumulated between the years 1920 and 1940.

Preparations have almost been completed for the Western Branch of the National Air Photo Library. This unit will be located in the Institute of Sedimentary and Petroleum Geology of the Geological Survey of Canada at Calgary, and will maintain a file of federal government air-survey photos covering the four western provinces, Northwest Territories, Yukon, and the Arctic Islands.

Mail was received from over 50 universities, and 14 nations.

Map Distribution. During the past twelve months, distribution facilities for maps, air charts, and *Canada Air Pilots* were further integrated. Automatic data-processing equipment is being installed to control the more than 22,000 items in the map inventory. The accounting system was modernized and adapted to a monthly printout of customer account statements on an IBM 407 computer.

The number of maps and air charts distributed to civilian clients rose to 1,871,492 during the past year, and the distribution to the Canadian Forces rose to 1,852,075 during the same period. This was an increase of 18 per cent over the previous fiscal year.

This office acquired the distribution of the *Canada Air Pilot* series from the Department of Transport. Since most of the items in this category are being printed in the Surveys and Mapping building, the transfer made for greater efficiency.

Bulk holdings of maps now stand at 16,789,244, an increase of only 598,626 maps and air charts during the year. More topographic maps were distributed than printed.

The distribution facilities for maps and air charts are being expanded with the establishment of a new distribution centre in the new Institute of Sedimentary and Petroleum Geology in Calgary. It will carry a complete stock of maps covering the four western provinces, the northern territories, and the western arctic islands.

SECRETARIAT, CANADIAN PERMANENT COMMITTEE ON GEOGRAPHICAL NAMES

Departmental reorganization resulted in the transfer of the former Toponymy Division, Geographical Branch, to the Surveys and Mapping Branch, where it became the Secretariat, Canadian Permanent Committee on Geographical Names. This unit maintains name records, advises the Permanent Committee and mapping agencies on nomenclature and conducts regional investigations into geographical names. It is also responsible for advising on geographical terminology and for the production and maintenance of the Gazetteer of Canada.

During the fiscal year 1967-68, the secretariat investigated almost 11,000 names, and nearly 4,000 new names were officially approved. The nomenclature was verified for 159 maps and charts, and over 500 inquiries concerning geographical names from members of the committee, the mapping agencies, other government departments and the general public were answered. Work continued on the *Gazetteer of Quebec* and the revision of the *Gazetteer of Manitoba* was completed. The second edition of the *Gazetteer of British Columbia* was published in early 1967 and the first edition of the *Gazetteer of Newfoundland and Labrador* in early 1968. Work was begun on the revision of the *Gazetteer of Saskatchewan.*

Field investigations were carried out in the Muskoka Lakes region in Ontario and a comprehensive study began of the nomenclature of New Brunswick.

The committee contributed four preliminary papers to the first United Nations Conference on the Standardization of Geographical Names held in Geneva in September 1967, at which Canada was represented by the chairman, the executive secretary and two provincial members of the committee. The annual meeting was held in Fredericton, where the committee endorsed the use of a standard orthography for the Eskimo language. During the year, the committee approved the naming of a feature in honour of the late Governor General George Vanier and the changing of the name Lake Saskatchewan to Lake Diefenbaker.

Geological Survey of Canada

The Geological Survey is responsible for the systematic geological investigation in Canada, and as the major organization engaged in this field in Canada its studies are nation-wide. During the report period, the Survey marked its 125th anniversary, and, in conjunction with Canada's Centennial Year, it hosted several national and international symposia. The main objectives of the Survey are to investigate systematically, describe and explain the geology of Canada in order to determine the nation's potential mineral resources and to provide industry and other governmental agencies with basic data required for the discovery of mineral deposits. The Survey also carries out research that will contribute to our knowledge of how and where the rocks of the earth and their contained mineral deposits were formed, research and development of new instruments and methods as aids to the search for mineral deposits and for geological investigation,

and assists in operational research training in the geological sciences and the supporting techniques to meet the requirements for qualified manpower.

In 1967-68 the Survey provided support for 26 doctorate-theses projects through summer employment. A total of 70 graduate assistants were employed in the field and 37 in the office; 123 student assistants were attached to various field parties and 53 were assigned to office duties.

During the 1967 summer season 99 full-time field parties conducted investigations designed to continue the systematic geological investigation of Canada. In addition there were 75 part-time projects, most of which were collecting support data for other research. Two large, multi-discipline, helicopter-supported reconnaissance projects were carried out. One of these initiated a two-season mapping program in the rugged terrain of northern Labrador and northeastern Quebec. The other saw the mapping in one season of Hudson Bay Lowland, an area of more than 130,000 square miles. The activities of the smaller parties ranged from detailed studies of recently discovered base-metal deposits in Yukon Territory to aeromagnetic investigation of Baffin Bay and the North Atlantic Ocean; from a mineralogical study of asbestos deposits to a study of indicator minerals in eskers; from marine geological investigations of the North Atlantic to dam-site investigation in northern Ontario and geological engineering studies near the site of the new Welland Canal.

To stimulate and support geological research at Canadian universities, 90 grants totalling $185,000 were awarded to 21 universities.

The scientific results of the Survey's work are published as memoirs, bulletins, papers, geological maps and to some extent as contributions to scientific journals. During the period covered by this report, 3 memoirs, 9 bulletins, 1 economic geology report, 2 miscellaneous reports, 78 papers and 16 geological maps (excluding those used to illustrate the preceding reports) were issued. About 350,000 copies of reports and maps were distributed, mainly from the Ottawa office, although about 10 per cent of the total distribution was from the Vancouver office.

The Geological Survey library, the most extensive of its kind in Canada, had a circulation of 50,712 items during the report period. In addition nearly 6,000 inquiries were answered, of which about 1,500 required information searches.

In addition to the headquarters in Ottawa the Survey maintains offices in Vancouver, Whitehorse and Yellowknife. The Calgary office was incorporated into the newly formed Institute of Sedimentary and Petroleum Geology, a division of the Survey, at the beginning of the report period.

BIOSTRATIGRAPHY

Fossils are of great importance to the geologists who need to know the regional and intercontinental equivalents of stratified rocks, knowledge that is of great importance in the search for the fossil fuels—oil, natural gas and coal. During the report period paleontologists of the division prepared 158 reports on 2,818 lots of fossils. Although most of the collections were submitted by Survey officers, about 475 came from industry, universities and individuals. In Canada and elsewhere more than 30 experts on particular groups of fossils or students working under the supervision of such experts studied Geological Survey material, studies that either resulted in reports to scientists or in publications. Nineteen geologists from universities, oil companies, and from other countries made use of the Survey's fossil collections or consulted with staff members.

Investigations on the petrology of Canadian coal and Paleozoic palynology were continued and fundamental research on the origin and effects of geological conditions on the various coal constituents was undertaken. Drilling by the Nova Scotia Department of Mines at the Pictou coalfield, carried out under the guidance of the Survey's Coal Research Section, was completed and revealed the presence of 300,000 tons of mineable coal. Research on coking coals was continued with emphasis on the Crowsnest coalfield, which is of particular interest because of the recently completed long-term sale of coal from this field to Japanese interests.

CRUSTAL GEOLOGY

The prime objective of the Crustal Geology Division is to study and interpret the folded, metamorphosed and igneous rocks that form the earth's crust in Canada in order to provide basic data required to forecast, find, and evaluate our mineral resources and to provide scientific knowledge on the origin and evolution of the earth's crust under Canada. Sixteen field parties carried out studies in the Cordilleran and Pacific Margin region, twenty on the Canadian Shield, six in the Appalachian region, and six on projects designed to support research into geochronological and petrological subjects.

In the Cordilleran region current activities consist mainly in the completion of the reconnaissance phase of the regional investigations in which data and conclusions on structure and stratigraphy are integrated to develop a broad tectonic picture. During 1967 field work was completed on several systematic reconnaissance projects including Operation Selwyn, a 25,000-square-mile mapping program in southeastern Yukon, and McBride, Lardeau, Mount Waddington and Alberni map-areas in British Columbia. Detailed studies were carried out in the Anvil Range of central Yukon to aid mineral exploration in the region surrounding the Faro, Vangorda, and Swim base-metal deposits. As most of the geologists associated with Cordilleran geology are stationed at the Survey's Vancouver office, they are frequently consulted by businessmen engaged in the exploration and exploitation of the mineral resources of British Columbia and Yukon Territory and this provides a useful and practical public service.

The Precambrian Shield Section is responsible for the study of the nearly 2,000,000 square miles of "foundation rock" which forms the Canadian Shield and which contains so much of Canada's metallic mineral wealth. Thanks to the advent of the helicopter and other recent improvements in transportation, the reconnaissance study of the Shield is almost complete; the only large unmapped tracts remaining are central and northeast Baffin Island, parts of northern Labrador and Quebec, Southampton Island and northern Melville Peninsula in the central Arctic, and certain areas along the north shore of the St. Lawrence River.

The major reconnaissance carried out in 1967 was Operation Torngat, during which 30,000 square miles of rugged terrain in northern Labrador and northeastern Quebec were mapped with the use of helicopters. Helicopter support was also shared by parties working in southern Keewatin District on problems concerning granitic and metamorphic rocks and a sedimentological and stratigraphic analysis of the Hurwitz Group. A study of volcanic rocks in the Shield was continued by the sampling of 782 volcanic units in the Timmins-Kirkland Lake-Noranda region.

Several members of the staff continued specialized research by spending periods of several months at universities and research institutes in Canada and the United States. A series of seminars was given by guest experts, staff members, post-doctoral fellows and Ph.D. candidates during the year. These seminars kept the sectional staff abreast of recent developments in Precambrian geology.

The Appalachian, Eastern Lowlands and Atlantic Margin Section studies the composition, stratigraphy and structure of post-Precambrian rocks in these various regions of Canada (including the Hudson Bay Lowland) and evaluates the implications of these features on the potential for mineral and petroleum resources. Field investigations were carried out in Burgeo, Burlington Peninsula and the Great Northern Peninsula in Newfoundland, in Cobequid Mountains and Antigonish areas of Nova Scotia, and in McKendrick Lake area of New Brunswick. A major helicopter-supported reconnaissance of the lower Paleozoic rocks of Hudson Bay Lowland was carried out; a map including the preliminary results of this investigation which covered 130,000 square miles was published early in 1968 and was of considerable interest to oil companies.

Members of the Petrology Section continued studies of ultramafic and granitic rocks, the role of water in metamorphic and igneous rocks, meteorites, and ocean-bottom sampling off the East Coast. The section also provided advice and specialized petrographic services to staff officers, and looked after the rock, thin-section and meteorite collections of the Survey.

The year under review was an eventful one for the Geochronology Section whose members are responsible for research, development and services in isotope geology, and for co-ordinating the Survey's age-determination and stable-isotope-investigation program. New facilities became available and new experimental procedures were perfected, so that it has been possible to inaugurate new methods of isotopic dating. The age-determination program was continued, and 215 K/Ar sample extractions were completed. Suites of rocks were collected from 12 localities for Rb/Sr whole-rock isochron dating and isochron ages were successfully completed for 10 of the suites. The Canadian Isotopic Age Data Centre, established to meet Canada's international obligations to the International Council of Scientific Unions, will include data derived from research at the Geological Survey along with those from other Canadian and foreign institutions.

EXPLORATION GEOPHYSICS

The Exploration Geophysics Division makes geophysical surveys as an aid to the understanding of the geology of Canada and carries out research on the development of new methods and instruments. During 1967-68 aerogeophysics was accelerated with the installation of a high-resolution magnetometer in a Queen Air aircraft, the lease of a Skyvan aircraft for gamma-ray spectrometry and remote airborne sensing, participation in an airborne infrared scanning program, and increased airborne electromagnetic work.

In October 1967 the Geological Survey and National Research Council sponsored the Canadian Centennial Conference on Mining and Groundwater Geophysics which was attended by more than 550 delegates representing 51 countries. Officers of the division were deeply involved in this most important conference as they were in an Earth Science Symposium on Hudson Bay which was held in Ottawa in February.

During the 1967 field season about 25 parties were active for varying periods of time. Their activities included seismic studies, ground gamma-ray spectrometer survey and palaeomagnetic measurements. The co-operative aeromagnetic project with the National Aeronautical Establishment was continued and investigations were carried out in the Arctic, over the North Atlantic Ocean, and near Ottawa. Contracts were let for aeromagnetic surveys in the area of the Polar Continental Shelf, in central Baffin Island, and in the District of Mackenzie.

GEOCHEMISTRY, MINERALOGY AND ECONOMIC GEOLOGY

This division studies mainly those aspects of geology that contribute most directly to our knowledge of the occurrence of economically important elements and minerals, the search for mineral deposits, and methods that may be useful in prospecting. The division contains the following sections: Geochemistry, Geology of Mineral Deposits, Mineralogy, Analytical Chemistry, Geomathematics and Data Processing, and a Special Projects unit.

The major research projects during 1967-68 were (1) the co-ordinated study of the geology of mineral deposits by a group of economic geologists, each of whom is responsible for a group of economic elements; (2) the development and testing of geochemical prospecting methods; (3) mineralogical studies of ore and rock-forming minerals; (4) the long-term implementation of a geochemical census of economic elements in the crustal rocks of Canada.

In the first category, work was continued on the preparation of a map showing the distribution and general geological environment of nickel deposits in Canada; a study of iron-sulphide, carbonate and oxide mineral-phase relations was initiated; a metallogenic index map for copper deposits in the Cordilleran region was nearly completed; study of the geochemistry of carbonate-lead-zinc deposits was continued; studies of lithium, tin, and beryllium and a metallogenic study of the Cassiar batholith were continued; a major report on uraniferous conglomerates was completed; a metallogenic map for Canada (a contribution to the International Geological Congress held in Prague, August 1968) was prepared; and development work on chemical field tests for detecting rare-earth elements was continued.

Geochemical techniques designed specifically for Canadian conditions are being developed and studies are in progress on the migration of elements from known ore deposits in glacial tills, the soil and stream sediments derived from these tills and the vegetation growing on them. Rapid analytical methods and computerized methods of data interpretation now make it possible to study seriously the composition of the rocks of Canada. Such data will be of value not only to geology but to other disciplines such as agriculture and health. These data are also expected to be of great value in developing deep-exploration methods. Thus it seems possible that geochemical methods can establish the probability of ore deposits in certain rocks at depth, and drilling may be carried out on the basis of this probability.

Mineralogical studies made by the division cover the physical and chemical properties of minerals and the geological significance of mineral associations and textures, and use X-ray diffraction, X-ray emission and absorption, and electron-beam techniques. The Survey's mineralogists provide a wide range of services to staff members, compile and publish data on Canada's minerals, examine rock and mineral specimens and prepare rock and mineral collections for sale as a public service, and catalogue and develop the National Mineral Collection and the Systematic Reference Series. During 1967-68 more than 6,500 sets of rocks and minerals were sold and 868 samples examined.

Chemical and instrumental analyses were continued to provide compositional data on geological materials. A total of 68,668 individual determinations were made. Work continued towards the development of geomathematical and data-processing techniques. Three senior staff members carried out special projects. A revision of *Prospecting in Canada,* which has sold about 30,000 copies so far and ranks as one of the Department's best sellers, was nearly completed during the report period and a report on the Walton, Nova Scotia, barite-sulphide deposit was completed. The co-ordinator of the Geological Survey's uranium research carried out field studies and organized study sessions at the

Vancouver office, the Institute of Sedimentary and Petroleum Geology, Calgary, and at Ottawa. These sessions helped to alert those working in areas favourable to uranium deposits and to brief them on the guidance to be offered in response to public enquiries about uranium prospecting.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

This division of the Geological Survey is a natural outgrowth of the regional office set up in Calgary in 1950. Its task is to discover, through field and laboratory research, the geology of the western and northern sedimentary basins from the International Boundary to the Arctic Islands and between the Canadian Shield and the Rocky Mountain Trench. The scientific work of the Institute is carried out by 6 research sections, which in 1967-68 were made up of 33 scientific and professional staff, 19 technical staff and 13 administrative support staff. The Institute collaborates closely with other government agencies, universities, scientific societies, and industry.

Field work was carried out by several parties of the Arctic Islands Section mainly on western Devon Island and Ellesmere Island. Five staff members of the Structural Geology Section undertook investigations in Canada's sedimentary basins. Studies of structural fabrics in coal measures in the Cordilleran and Appalachian regions were continued. Members of the Paleozoic Stratigraphy Section provide basic research towards establishing a stratigraphic and historical framework both in outcrop and subsurface for Paleozoic rocks in Western Canada. During 1967-68 plans were made for Operation Norman, a two-season helicopter-supported reconnaissance designed to map 115,000 square miles in the District of Mackenzie. One member of the section planned and conducted a graduate seminar at the University of Calgary. The Mesozoic Stratigraphy Section carried out studies in Saskatchewan, Alberta, northeastern British Columbia, Ontario, and the Arctic Islands. These studies, designed to determine the lithological variations, stratigraphic relationships, and the potential as source rocks and/or reservoirs of oil, gas, and coal, for Mesozoic rocks, are carried out in collaboration with areal geological, paleontological and palynological studies. The Paleontology Section of the Institute is responsible for research in paleontology and biostratigraphy in western and northern Canada. A total of 1,104 lots of fossils were examined and 40 individual reports were prepared. In addition 13 reports on 384 lots of fossils were prepared by outside experts for Survey officers. The Petroleum Geology Section, formed late in 1967, held extensive discussions with key members of industry and with provincial and federal government organizations in order to establish the Survey's role in relationship to the oil industry. As a result of these discussions it is felt that the general areas of interest in which the Institute could be most useful include the following: (1) broad, regional subsurface studies; (2) geochemical investigations, particularly organic geochemistry; (3) detailed paleontology; (4) broad studies of already discovered oil and gas accumulations.

QUATERNARY RESEARCH AND GEOMORPHOLOGY

This division was formed during the report period by the amalgamation of former units of the Geological Survey and Geographical Branch. It provides scientific knowledge of unconsolidated deposits and landforms, the processes that modify the landscape, and the history and physical and biological environments on the earth during the Quaternary, including information pertinent to forestry, agriculture, engineering, groundwater, and mineral exploration.

Members of the Regional and Stratigraphic Projects Section undertook field work in seven provinces and the Northwest Territories in 1967 in order to prepare geological and geomorphic maps and reports designed to provide both a regional scientific framework and information of value to those engaged in studies of forest and agricultural soils, groundwater occurrences, engineering factors in construction, and mineral exploration. Inventory mapping of the glacial and related deposits in the Prince George, British Columbia, area was completed and reconnaissance studies of the glacial geology and geomorphology of southern Ellesmere Island were begun during the report period. Among the other projects undertaken by the section during the 1967 field season was the mapping of the Quaternary geology of the Hudson Bay Lowland. The completion of this work filled a large gap in the knowledge of the geology of this part of Canada. Studies were undertaken in southwestern New Brunswick to provide areal data pertinent to groundwater occurrence.

The Sedimentology and Geomorphic Processes Section investigates processes of landscape change involving slope movement and erosion, frost action (including permafrost), weathering, sediment movement, and sediment accumulation. These studies provide basic data, background information for interpretation of rocks and soils of earlier time, and information that is significant in forestry, agriculture, and in engineering studies and mineral prospecting. During the past year the work of the section has included an analysis of the stratigraphy, sedimentary structures, texture, and mineral composition of varved sediments and an interpretation of their depositional environment. Reports on sedimentation in Lake Erie and Lake Ontario were prepared for the International Joint Commission.

The Paleoecology and Geochronology unit provides radiocarbon dates and analyses of fossil materials (particularly pollen). It also determines variations in radiocarbon content of modern materials as background for other research, investigates the chronology of fossil-bearing deposits, and conducts research on changes in environment and in plant and animal distribution during the Quaternary.

The Engineering and Indicator Geology unit applies Quaternary studies to engineering and mineral exploration. Research is carried out on those aspects of geology that affect the engineering behaviour of soils, and geological investigations of engineering sites or problems are made by the unit on request from governmental agencies. Methods of mineral exploration that involve tracing indicator materials in glacial or other unconsolidated deposits to their bedrock source are also undertaken. An interesting application of this technique resulted in extensive prospecting in the Kirkland Lake area of Ontario for kimberlite, which in South Africa is the host rock for many diamond occurrences.

Mines Branch

The Mines Branch is a complex of laboratories and pilot plants designed to assist the Canadian mineral industry in the more efficient extraction and elaboration of mineral wealth of all types, and to improve and broaden the uses of metals and minerals. During the twelve months under review the Branch continued a number of promising research projects and started several new ones.

The work is carried on in six divisions – Physical Metallurgy, Fuels Research Centre, Mining Research Centre, Mineral Sciences, Extraction Metallurgy, and Mineral Processing.

Physical metallurgy is concerned with the composition and behaviour of pure and alloyed metals as well as the smelting of iron and steel. Much of the work falls into the category of "troubleshooting" for government departments and private industry.

Fundamental research into the melting and solidification of metals and the physics of liquid metals also forms part of the division's work. Research on fuels concerns especially the treatment of Canadian coals so as to render them more acceptable to the metallurgical industry at home and abroad, the chemical structure of hydrocarbons, and the beneficiation of Canadian heavy crude oils. The Fuels Research Centre also seeks to improve the safety of mining equipment in explosive atmospheres and to reduce air pollution from combustion.

Mining Research Centre specialists concentrate on such problems as rock breakage, ground and dust control, managerial operations control, and the distribution of technical information to the mining industry. In mineral sciences, the emphasis is on the composition and properties of useful minerals. The complicated sulphides occupy much attention, as do multi-oxide systems of such elements as niobium, tantalum, and aluminum. Research is also being conducted on the fabrication of piezoelectric and magnetic ceramics, surface phenomena on minerals, and crystal structure. In the Extraction Metallurgy Division, bacterial leaching of uranium ore, an experimental shaft-and-electric-arc furnace, prevention of embrittlement during electroplating, and the thermodynamics of metallurgical reactions are the main fields of interest. Research in mineral processing covers practical aid in the processing of newly discovered ores, the evaluation of commercial ceramics, the improvement of industrial minerals such as shales and concrete, and the flotability of non-metallic minerals.

Details of these and other investigations will be found in the following.

PHYSICAL METALLURGY DIVISION

The Division carried out both fundamental and applied studies concerning improved properties and processing of metals and alloys for many diverse applications in industry, public service and national defence.

To mark Canada's Centennial, a seminar was presented on June 12 and 13, at which twenty papers on the work of the Division were presented by staff members. Visitors from across Canada, Great Britain and the U.S.A. attended, and many took the opportunity to visit the laboratories and to discuss technical matters with Divisional staff.

As in previous years, the Division continued to meet many requests for consultation and technical advice on metallurgical problems from industry as well as from other government departments and agencies. A total of 43 *Investigation Reports* and 23 *Test Reports* were issued in connection with work done on such problems. Some 116 requests for metallurgical information were received and dealt with for the Technical Information Service of the National Research Council, and 126 reports and publications were prepared and issued during the period.

The facilities of the Divisional laboratories were extended to six outside organizations including the Steel Castings Institute of Canada, Canadian Zinc and Lead Research Committee, National Aeronautical Establishment, Falconbridge Nickel Mines, Canadian Westinghouse, and Noranda Research Laboratories. These organizations supply one or more employees who work on specific assignments in conjunction with Divisional staff.

Outside activities of staff members included 50 lectures and papers presented to learned societies and technical groups in Canada and abroad, in addition to the Centennial seminar referred to previously.

The work of the Division may be divided into two broad classifications: research, both fundamental and applied, and investigational activities which may be urgent as well as long-term. Investigation of failed or damaged metal components, particularly in

industrial and military equipment, has long been an important service, especially when it is possible to recommend preventive measures. During the past year many such investigations were made. They included examination of cast ship's propellers, steel plate from ship's hulls, broken spring from large ore-sizing-screen installation, gun barrel, rail steel, and ruptured and corroded boiler tubes among ferrous components. Of some technical and historical interest was an investigation of some wrought-iron nails recovered from sunken ships in Georgian Bay in an attempt to establish the age of the vessels. The metallurgical character of some of the nails indicated manufacture in the period 1800-1870. Investigational work on non-ferrous alloys included examination of defective small-arms ammunition cases, manganese-bronze ship propellers, magnesium alloy components of military shot, and defective connectors for solar cells. At the request of the Ontario Fire Marshall's office a section of extruded aluminum-alloy window frame recovered from a hospital fire was examined to estimate the temperature of exposure.

In other fields investigation of failures of welded gas pipelines continues to provide useful information for improvement in material and welding quality. Investigations of welding problems associated with rocket launchers and battery connections in space satellites indicate that Mines Branch work keeps pace with the latest scientific developments.

The Division acts as the examining aauthority for the certification of industrial radiographers on behalf of the Canadian Government Specifications Board. In 1967, written examinations were held at nine centres across Canada and practical tests conducted in Ottawa, Edmonton and Victoria. During this time, 83 junior-grade and 30 senior-grade industrial radiographers were successful in their examinations for certification. There are now 180 senior-grade and 430 junior-grade certified industrial radiographers in Canada.

Radiographers can now be certified in the category of "Aircraft Structures." Practical tests on aircraft are conducted at the Air Force Base, Trenton, Ontario, under the direction of the examining authority.

Fundamental and applied research provides many of the bases for current and prospective improvements in materials and processing technology. Work of the Division in these areas is directed to matters of particular significance to the Canadian scene, particularly in iron and steel research. Studies of the solidification process and the development of controlled-cast structures, it is hoped, will lead to material improvement in casting quality and superior mechanical properties. Research into new and improved melting and refining techniques, degassing and inclusion elimination as well as alloy development are all important continuing activities. The direct measurement of oxygen content in molten steel by means of an electronic probe has been developed to the stage where commercial interest has been aroused.

Research of more fundamental nature is being done in such areas as the physics of liquid metals, studies of segregation using radioisotopes, fatigue characteristics of zinc, brittle fracture, hot-working and recrystallization of face-centred cubic metals, studies of forgeability, among many other projects. All of these relate directly or indirectly to applied research and development problems, it being an objective to maintain a realistic balance between research in fundamental metal science and applied metallurgy.

FUELS RESEARCH CENTRE

The production of mineral fuel is undergoing many changes all over the world, and this is strongly reflected in the activities of the Fuels Research Centre, which is concerned

with the numerous aspects of chemical-process engineering required to transform coal, low-grade petroleum and natural bitumen into industrially acceptable products.

A most significant turning point for the coking-coal industry of Western Canada occurred during the year. This was the signing of contracts for the export to Japan of about 5½ million tons of coal per year over the next fifteen years. Deliveries are to begin during 1970-71. Contracts for an additional two million tons per year may be concluded in the near future. Over the fifteen-year delivery period this would expand the total market for Western Canadian coking coal to 1½ billion dollars.

To insure the continuance and expansion of these markets, the Fuels Research Centre has attempted to maintain and improve its processing capability on the pilot scale, so as to reduce new technical innovations to practice as quickly as possible. This service is essential for the Canadian coal industry, as its wide geographic dispersion prevents this type of work from being performed by individual companies. The advanced state of Japanese technology and scientific facilities requires that Canadian laboratories maintain the highest standards to insure a satisfactory dialogue with this purchaser.

In this connection, the progress on the relocation of the Fuels Research Centre on the western outskirts of Ottawa is encouraging. The indications are that at least some of the buildings will be ready for occupancy in the fall of 1968. A program to modernize the laboratory facilities associated with the relocation has been under way during the past year in preparation for this move. The purchase of new equipment for the construction of a modern 18-inch oven, which will carbonize an 800-pound charge of coal, is substantially complete, and installation will commence as soon as the state of construction at the Corkstown Road site permits. This particular research is conducted by the Metallurgical Fuel Engineering Group which works closely with the metallurgical industry to find new techniques of matching Canada's coal resources to the special needs and requirements of this industry.

Satisfactory progress has been made during the year on the removal of pyrite from Cape Breton coals destined for use in the local steel industry in the form of coke. This experimental work has made it possible for engineering consultants to arrive at a cost estimate of pyrite removal acceptable on an industrial scale and employing established coal-cleaning technology.

The outcome of this engineering study was sufficiently encouraging to justify further work in the laboratory to grind the coal to much finer levels to liberate the pyrite. The fine grinding of coal creates new problems, as this operation impedes the elimination of moisture. It also becomes necessary to reconstitute the coal into particles sufficiently large to be suitable for carbonization. Considerable progress was made during the year on the agglomeration of coal fines by the formation of spherical agglomerates in water with coal tar.

The research of the Hydrocarbons group of the Fuels Research Centre, in broad terms, has been directed to three main areas: the evaluation of Canadian petroleum resources (including engineering studies of transportation and comparisons of Canadian fossil fuels); a better understanding of the fundamental chemical structure of these raw materials; and, finally improved processes to beneficiate Canada's heavy crude oils to supply the needs of the future.

A directory of Canadian oil analyses and reservoir data has been compiled and is in the process of being submitted for publication. This directory includes most of the crude-oil analyses performed over several decades in the laboratories of the Fuels Research Centre and is fairly representative of all significant Canadian oil fields. Typical field data and secondary recovery data are also included for most of the more important

oil pools. It is hoped that this publication – one of the most complete of its kind – will provide interested research workers with the documentation needed for comparisons of various oil reservoirs in all the oil-producing provinces of Canada.

Emphasis in applied petroleum research is the development of processes and equipment for the conversion of Canadian low-grade crude oils, bitumens, coal tar, and petroleum residues to more useful and more valuable products. One of the most important preliminary process steps is the removal of finely divided mineral matter from heavy oils. Mild thermal cracking to reduce the viscosity of the oil has been found to facilitate the removal of mineral matter by centrifugation without having any deleterious effect on the subsequent hydrogenation steps.

An important contribution to the safety of mining in Canada has been made by the Canadian Explosive Atmospheres Laboratory. This laboratory conducts research to reduce the hazards associated with using electrical equipment in the explosive atmospheres that commonly occur in coal mines. One special aspect of this service that has increased rapidly during the year has been the approval of fire-resistant conveyor belting certified by this laboratory as safe for underground use. The provinces of Saskatchewan and British Columbia now require all underground belting to meet this standard. This requirement arises from the rapid growth of the potash industry in Saskatchewan and the more stringent view taken by the mining inspectorate of British Columbia concerning the dangers associated with the combustion of conveyor belting in any underground workings.

The certification of coal-cutting equipment, compressors, electric motors, diesel engines, and performance tests on gas detectors is proceeding at an accelerated pace. There are strong indications that the demand for this service will increase annually.

The research of this laboratory has concentrated on two areas: the transmission of flames through narrow gaps that simulate those present in flame-proof equipment; and the ignition of combustible gas-air mixtures by sparks of inductive circuits. New equipment has been designed and built to study the energy release in sparks produced by instruments for testing intrinsically safe circuits.

Air pollution has recently aroused public concern. One special aspect of this problem involves the control of air pollutants caused by combustion. Research in this field is carried out by the Canadian Combustion Research Laboratory at an accelerated pace to alleviate some of the pollution in the major population centres. A significant advance has been made during the year in the development of a new plume-rise equation, which predicts the manner in which stack gases are dispersed from tall chimneys. This will make it possible for smoke stacks to be designed in a much more satisfactory manner as regards health standards.

The changing pattern of fuel use in many areas of Canada, from coal to oil, has emphasized the need to find new methods of reducing the amount of acid soot production that occurs on burning heavy oils. Research to overcome this atmospheric pollutant has made considerable progress. Additives have been found which suppress sulphur-trioxide production. This enables electrostatic precipitators to be used to virtually eliminate the release of soot into the atmosphere. These additives have an additional benefit in that they substantially reduce the corrosion in the cooler parts of large thermal power stations.

MINING RESEARCH CENTRE

Research Orientation. Government enterprise is needed in Canada to supplement the broad mining research carried out by companies and universities that requires lengthy and uninterrupted effort and whose ultimate benefit accrues either to the entire industry or the economy of the nation. To support basic studies on problems common throughout the industry, many cooperative projects are pursued with separate companies, the cost being shared by company and government.

With declining average grades of orebodies and deepening mines, there is a growing need for conservation, in the sense of making extraction less wasteful. Therefore, some of the Mining Research Centre's research concentrates on the more complete extraction of ore values from mineral deposits. This is a field that is particularly suited for government research, since the expenditure of money on ways and means of processing difficult ores may not always appeal to individual companies, which may find it more profitable to look for new orebodies abroad.

Operating efficiency is good in the Canadian mineral industry, but it could be better. With the world's third largest mineral industry, Canada should be a leader in mining technology. Research on systems as well as on physical problems will improve the competence of Canadian management and technical personnel, so that investors will have more confidence in native enterprise and thereby reduce the need for so much foreign investment.

Research Programs. Rock-breakage research is concerned with freeing the ore from the host rock and breaking it down to a pulp suitable for processing. Improvements can be made in drilling and blasting, on which the industry is currently spending $100,000 per year, leading to payoffs many times greater than the research cost. As a result of a survey made by the Mining Association of Canada some three years ago, the fundamentals of non-explosive rock breakage are also being studied with the prospect of evolving novel methods of mining.

Research on ground and dust control is concerned with the stability of the host rock after the ore has been excavated and with the maintenance of atmospheric conditions suitable for human activity. Mines, faced with growing competition for technical personnel from other industries, are having to make great efforts to improve working environments. Environmental conditions vary widely, according to commodity – salt, potash, coal, asbestos, base metals, gold, uranium – and no single answer will solve all the problems.

Mining systems engineering is being introduced to apply advances made in other types of research to mine operations. Operations research conducted by a group of engineers, physicists and mathematicians is expected to produce new analytical tools for mine managers and engineers, such as computer-program packages complete with operating instructions.

Communications. An information office is being set up in the Mines Branch to serve industry and the universities. It is being increasingly recognized that one of the functions of a central agency serving industry is to cull from the vast outpouring of research and technical data those elements that are important for the solution of immediate industrial problems. Before long this office will be able to supply on request (through a direct telex link) bibliographies of articles pertinent to specific problems as well as copies of papers containing practical data.

The Canadian Advisory Committee on Rock Mechanics has guided the Mines Branch in stimulating research and the training of post-graduate students in universities. The grants in aid began in 1962 with $10,000 and, thus far, have disbursed $320,000 to Canadian universities. This has helped to increase significantly the number of graduate students coming out of the mining departments of Canadian universities and to expand the volume of coordinated rock-mechanics research throughout the country.

MINERAL SCIENCES

During the period under review, the work of the Mineral Sciences Division has continued to be concerned with a number of major research programs. To the eight such programs described in the previous annual report there has been added one dealing with the use of applied mathematical techniques in the mineral industry. In addition, late in 1967, personnel was reorganized in order to achieve a closer alignment of the groups with the projects under study. Included in this reorganization was the creation of a group concerned with crystal structure, another with crystal growth, while the former mineral physics section has been divided into three groups concerned, respectively, with solid-state studies, mineral surface phenomena, and with instrumentation repair and maintenance. The description that follows will give a résumé of the progress achieved in the main research programs.

Sulphide Research. A wide variety of experimental techniques has been and continues to be applied to the study of many natural and synthetic mineral sulphides, arsenides, sulpharsenides and antimonides. The techniques include single-crystal growth by the vapour-transport and Czochralski methods, phase-equilibrium studies, investigation of the optical and magnetic properties, crystal-structure studies leading to information on bond types, also chemical, analytical and infrared spectroscopic studies. The sulphides so far included within the scope of the program include those of zinc, iron, copper, cobalt, nickel, cadmium and lead and many complex sulphides and related compounds containing two or more cations. Electron-probe microanalysis has proved to be very useful in following the distribution of elements in complex natural and synthetic sulphides. The various techniques, when combined, have gone a long way towards explaining the structure and properties of these minerals.

Oxide Phase-Equilibrium Studies. The work on the phase-equilibrium of multi-oxide systems continues to be a significant long-term line of research. The investigations of the systems CaO-Nb_2O_5-TiO_2 and CaO-Ta_2O_5-SiO_2 have been largely completed during the review period. Interesting differences between the behaviour of tantalum and niobium have been revealed by a comparison of the results obtained on the CaO-Ta_2O_5-SiO_2 system with those obtained on the analogous niobium system investigated some years ago in this Division. The CaO-Nb_2O_5-TiO_2 system has given interesting results related to the mineralogical occurrences of minerals having the perovskite and pyrochlore structures. Further work has been done in the hope of resolving some of the complexities of the CaO-Al_2O_3-Fe_2O_3-SiO_2 system. Preparations have been made to investigate the phase-equilibrium relationships in the Sn-O system; these will have metallurgical and technological significance in the electronic-ceramic field.

Analytical Chemistry Research. Much work has been done in continuation of the study of the absorption spectra of minerals and of solutions of inorganic complexes. The

use of ligand field theory has yielded much information concerning the configuration of the complexes and explaining the optical properties of the minerals, such as colour and pleochroism. The technique of atomic absorption spectroscopy has been found very useful in the analysis for a variety of metallic ions in otherwise intractable contexts. An accurate determination of the mass absorption coefficients of many atoms in the X-ray spectral region is under way for use in quantitative X-ray microprobe analysis.

Standards Work. The analytical personnel of the Division continue to be heavily committed to standard analytical procedures in both the national and international fields, collaborating in this work with the ASTM, the International Organization for Standardization, the Canadian Standards Association and the Spectroscopy Society of Canada. Most of this work involves the devising of acceptable standard methods for the analysis for metals, both as major and trace constituents, in a wide variety of ores, alloys, minerals and metallic products.

Piezoelectric and Magnetic Ceramics. Work on the preparation of piezoelectric materials based on the lead zirconate-titanate solid-solution series, being conducted on behalf of the Defence Research Board, was wound up at the end of the current review period with the expiry of the contract. Certain aspects of the study of factors affecting the sintering behaviour and electromechanical properties of these compositions still remain to be written up and/or published. The work on "hard" or permanent-magnet types of ferrites based upon lead/strontium/barium hexaferrite has been continued throughout the year. A study of the mechanism of formation of lead hexaferrite under various conditions has been completed and submitted for publication. Considerable work on the properties of mixed strontium/barium hexaferrites has been done. The work done in co-operation with a Canadian industrial organization with a view to characterizing its iron oxides and assessing their reactivity in the formation of ferrites continued sporadically throughout the year.

Canadian Ore Mineralogy. The comprehensive mineralogical investigation of the silver-cobalt deposits of the Cobalt-Gowganda area continued throughout the year. The study is concerned with the distribution of the metals amongst the various arsenides, sulpharsenides and antimonides present. The study of a suite of unusual minerals found in the deposits at Seal Lake, Labrador, also continued during various portions of the review period.

Surface Phenomena on Minerals. The surface properties of minerals, particularly with reference to their flotation behaviour, continue to be of interest to the Division. Studies during the past year have included the adsorption behaviour of oleic on hematite, of xanthates of sulphides, and of the double layer existing at the liquid-solid interface when a range of mineral oxide samples is contacted by aqueous solutions containing certain anions. Electrophoretic studies associated with bacterial leaching have been started, as has also a program of measurement of the contact angles at mineral/liquid interfaces.

Work on the adsorption behaviour of semiconducting materials in contact with electrolytes has been started. The initial working material in this study is synthetic single-crystal PbS.

Applied Mathematics. Work on sampling of particulate materials and of mineral deposits has been started with a view of ultimately exerting better grade control and of making more reliable ore-reserve estimates.

Crystal Structure. Studies of a number of materials such as certain sulphides and also some calcium vanadates are being made on behalf of the Defence Research Board. In this connection much work has been directed towards interfacing the automated four-circle goniometer equipment with an "on-line" computer. This system is now operating satisfactorily.

In addition to the above-mentioned research projects, the Division continues to conduct a large number of service investigations employing a variety of techniques such as wet-chemical and instrumental analyses, X-ray, infrared and emission spectroscopy, X-ray diffraction, electron-probe microscopy, differential thermal, thermogravimetric and neutron-activation analyses. These service investigations are conducted on behalf of other divisions of the Mines Branch, other government departments such as the Department of National Defence, the Department of Transport, the Canadian Government Printing Bureau, the Royal Canadian Mint and the R.C.M.P. Assistance is also rendered on request to industry and to universities in those areas where the Division has specialized facilities not available at these establishments.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, research was carried out on hydrometallurgical and pyrometallurgical processes, on electro-plating technology, and on causes and prevention of metal corrosion. At the same time, fundamental studies were made of the kinetics and thermodynamics of metallurgically important chemical reactions. Research covered fields of broad general interest to the metallurgical industry. Division staff kept in touch with metallurgical companies through the formal activities of co-operative industry-Mines Branch organizations such as the Canadian Gold Metallurgists (now Canadian Mineral Processors) and the Canadian Uranium Producers' Metallurgical Committee, through the publication of research results in technical journals, membership in professional societies, and many informal contacts.

It has been known from earlier work conducted in the Division that uranium can be extracted from Elliot Lake uranium ores by bacterial action almost as effectively as by the strong sulphuric-acid leaching now in general use. The rising cost of sulphuric acid has made bacterial leaching increasingly attractive economically, and as a result a project was initiated to adapt a semi-static leaching system, developed here earlier for acid leaching, to a bacterial leaching process. The results obtained so far indicate that adequate leaching rates can be obtained, along with substantial reductions in reagent and heat requirements, and that extractions will be only slightly less than with conventional acid leaching.

The leaching processes used for extracting uranium also yield substantial amounts of rare-earth elements as by-products. Because of the continued demand for refined rare earths, a research program was initiated to develop processes that will recover marketable rare-earth products economically from uranium-extraction effluents.

The establishment of a tungsten-mining and treatment operation in the Northwest Territories had earlier prompted the development of an improved method for the production of high-purity tungsten products from mineral concentrates. In some recent work the process was further improved by more efficient cation-exchange removal of impurities from the leach solutions, thus yielding tungsten products of even higher purity.

Mathematical analyses and mathematical simulation of metallurgical processes, which are beginning to receive attention in the metallurgical industry, are being developed and utilized in the Extraction Metallurgy Division as an important research aid in metallurgical research. These techniques have been applied to the evaluation of variables in both physical and chemical metallurgical systems.

In view of the electrical and hydrocarbon-fuel resources of Canada available to the metallurgical industry, further development work was carried out on the combination shaft-and-electric-arc furnace. The combination is designed to increase the efficiency of electric smelting by pretreating the incoming feed with the hot reducing electric-furnace off-gases, and augmenting these in some cases by oil or natural gas. This unit has now been improved by the installation of a better auxiliary-fuel-combustion system, and a rotating hearth in the electric arc furnace to improve charge distribution within the furnace. In the initial work on melting pre-reduced iron pellets, a saving of 33 per cent of the electrical-energy requirements of the furnace was achieved by preheating with natural gas in the shaft furnace.

A long-term program has been devoted to the improvement of industrial electroplating technology, particularly the prevention of hydrogen embrittlement of certain high-strength steels during electroplating. The improvements have consisted in the development of better cleaning and pickling procedures as well as plating baths. This program, which had already embraced the plating of zinc, cadmium and copper, was extended to the electroplating of silver, with the development of precise mathematical relationships between the bath components. The development of improved plating baths for the electrodeposition of brass is also under study, and a 70:30 brass can now be plated on high-strength steels of type 1062 without embrittlement.

Another long-term program has concerned the prevention of metal corrosion in industrial environments caused by the sulphurous acid formed from sulphur dioxide in the atmosphere. In earlier work, the causes and prevention of corrosion of mild steel were investigated, and addition agents such as sodium oxalate and hexamine were found to be effective in the prevention of corrosion when added to sulphurous-acid solutions in contact with the steel. In the course of these studies, mathematical expressions were developed for calculating corrosion rates. Similar expressions have been developed for calculating corrosion rates of tin, lead, cadmium, chromium and aluminum. In view of the importance of zinc as a material of construction and protection, a similar program was carried out with this metal, and here again the addition agents sodium oxalate and hexamine were found to be effective for the protection of zinc against sulphurous-acid attack.

In the basic research of the Division much effort was devoted to studies of the kinetics and thermodynamics of metallurgical reactions of importance to Canadian industry. An extended program was continued on the dissolution of the copper-bearing minerals digenite, chalcocite and chalcopyrite to clarify the mechanisms of the leaching reactions by experiments done on pure or synthetic minerals under specific conditions. Experimental work was completed on the kinetics of the thermal decomposition of zinc sulphate and zinc oxysulphate to zinc oxide, and also the thermodynamic relationships between various products in the manganese-sulphur-oxygen system, these last being of importance in certain industrial processes for atmospheric-pollution control. A study was initiated on the kinetics of the chlorination of cupric and cuprous sulphides with chlorine gas to yield copper chloride and elemental sulphur, and a literature survey was made and calculations completed on a theoretical study of the possibilities of chlorinating manganese, lead and zinc sulphides for recovering elemental sulphur and the appropriate metallic chloride. This program was extended to correlate the relevant data for the thermodynamic properties of molybdenum and tungsten in sulphur-chlorine and sulphur-oxygen systems.

The analytical facilities of the Division were substantially increased during the year by the installation of a Phillips 1220 X-ray fluorescence unit, which was particularly required in support of the rare-earth research. Atomic-absorption analyses were further developed for metallurgical analyses including gold, copper-nickel, tungsten-process products and smelting slags. As a preliminary to development of equipment and methods for on-stream analyses, improved analytical methods for alkyl xanthates and other flotation reagents were developed.

MINERAL PROCESSING

The Mineral Processing Division carried out basic and applied research in aid of the mining, ceramics and construction-materials industries and continued to supply expert technical advice to industry and other government departments.

Research to improve basic processes for concentration of metal ores included studies of grinding-process control, filtration of ultrafine suspensions, gravity concentration of asbestos and iron ore, and flotation of iron, tin and molybdenum ores. Papers on these processes were prepared for publication at national and international conferences.

Applied research was conducted to assist mining and metallurgy in development of new mines, improvements in existing plants, and better utilization of resources. Treatment processes were developed for important new mine projects, including copper-nickel, copper-lead-zinc, copper, gold-silver, niobium, tantalum, gold-silver-copper, gold, and lead-zinc ores.

A pilot plant was operated on a copper-nickel ore for three months to supply information on the feasibility and design of a new mine now being planned. Pilot-plant development of a tantalum ore has resulted in the construction of a mine as a source of this metal, hitherto produced only from imported placer concentrates. Laboratory and pilot-plant development of a process to recover iron and nickel from asbestos-plant tailings has led to a large industrial research project supported by the Department of Industry and the asbestos companies.

Fundamental studies were made concerning the effect of grain size and small quantities of special additives on the piezoelectric properties of lead-zirconate-titanate ceramics. The composition and properties of selected clays and shales from Quebec and the Maritimes useful to the ceramic industry were investigated. A quantitative relationship was established between the pierceability of rocks and thermal properties, such as thermal conductivity and thermal expansion. Methods of forming ceramics by isostatic and hot pressing were studied. A major study was carried out in which parameters were established for producing dead-burned magnesia from Ontario magnesite. Numerous samples of clays, shales and other industrial minerals were evaluated for use as ceramic raw materials for the ceramic and mining industries.

Assistance was given to industry by investigating improved manufacturing processes of coated and semi-coated expanded shale aggregates for use in lightweight concrete. A test procedure was developed for the Department of Transport, Marine Regulation Branch, for inclusion in the Canadian Concentrates Code, to determine the flow-moisture point in a mineral concentrate for shipment in marine vessels. Assistance was provided in compilation of pertinent information on samples of rocks, ores and minerals collected in the Geological Court, EXPO '67, for publication in a special brochure. Help was given in the planning of the relocation of the geological mosaic map of Canada from its site at the Canadian Pavilion to the grounds of this department after serving its time as an exhibit.

The method developed for accelerated testing of concrete is gradually being accepted for field uses by the construction industry. Hydro-Quebec has specified its use in some of

its concrete dams, and the City of Montreal installed the required facilities for this test in its concrete-testing laboratory in Montreal.

In the industrial minerals mill applied research projects on the flotability of non-metallic minerals, drying with radiant heat on vibrating conveyors, recovery of weakly magnetic minerals, and electronic sorting were advanced. Studies of materials handling with vibrating equipment and of ultrafine grinding with a vibrating mill were completed. Investigational work was performed on 31 materials originating in seven provinces, the Northwest Territories, and India. Particular emphasis was placed on a barite-fluorite ore from Cape Breton Island.

The division continued the long-term investigations related to asbestos and gypsum. A static method for determining the length-diameter relationship of chrysotile asbestos fibre has been developed, and further improvements based on additional study were made. Surface properties of chrysotile were studied on the basis of zeta potential, and dielectric properties of the fibre are being explored as a possible means of beneficiation. A simple, rapid method for surface-area measurement of chrysotile was developed by modification and use of a junior gas chromatograph. A study of the utilization of by-product synthetic gypsum derived during wet-process manufacture of phosphoric acid for the production of gypsum plaster was completed. A technique involving autoclave calcination of the wet gypsum slurry, based on French and British patents, was used to produce a satisfactory plaster. Beneficiation of gypsum containing clay and shale impurities is now under study.

Observatories Branch

The Observatories Branch is concerned with two major disciplines, astronomy and geophysics. Astronomy is studied in major observatories at Ottawa, Penticton and Victoria, and at a number of field stations. A major effort in 1967-68, combining the resources of both the Ottawa and Victoria observatories, was the continuing site-testing at Mt. Kobau, B.C.

There are three geophysics divisions: Seismology, which operates 27 seismograph stations plus an array for the detection and identification of nuclear explosions and which sends field parties to all parts of Canada; Geomagnetism, which studies the present and past geomagnetic fields through nine permanent observatories and a major laboratory, and conducts field surveys in all parts of Canada; and Gravity, which is involved in field work in all parts of Canada.

Because the public has a deep interest in astronomy a service must be provided to answer questions in astronomy and related subjects and to receive the public at the major observatories. The Ottawa observatory has produced the first five of a series of pamphlets on astronomy; these are in an attractive format and have been received with enthusiasm by educators and others. The series is currently being expanded. The observatory is also producing a series of illuminated wall displays on the various phases of its work.

Visitors to the Ottawa observatory numbered over 6,000 for the period under review; this number was made up of more than 100 group tours and about 3,000 visitors during the Saturday evening visiting program. The Victoria observatory received 32,000 visitors throughout the year, most of them during the daytime when they view the 72-inch telescope and a small museum, some of them on Saturday nights when they are permitted to see through the telescope. The Radio Astrophysical Observatory at Penticton discourages visitors since the ignition system of cars interferes with the operation of the telescope, but regular visiting hours are established on Sunday afternoons during the summer. No record is kept of their number.

ASTRONOMY DIVISION, OTTAWA

This Division carries out studies of fundamental star positions, provides the time standard for Canada, distributes time throughout Canada by wire and radio and carries out fundamental studies of the sun and of meteors and meteorites. It is also cooperating actively in the site-testing on Mt. Kobau.

The measurement of star positions requires very great accuracy. An instrument of new design, the Mirror Transit Circle, has been under development in Ottawa for several years. During the past year improvements have been made in the insulation and shielding of the piers and support members of the instrument because it was found that temperature fluctuations were distorting these members and producing erratic measurements. A number of modifications to the electronic controls to improve the facility of observations have also been incorporated.

The standard instrument for the measurement of time is the Photographic Zenith Tube. The PZT is a transit telescope especially adapted to measuring earth rotation and latitude variation, and when used with atomic timekeepers is a sensitive detector of irregularities in earth rotation. A PZT has been operated in Ottawa for many years. A second one, built jointly by the U.S. Naval Observatory and the Dominion Observatory, has recently been placed in operation. The original PZT will soon be moved to Calgary, where, in cooperation with the Royal Greenwich Observatory which is on the same latitude, it will be used in a long-term experiment to detect continental drift. During the year the Ottawa PZT was used on 168 nights for a total of 3,335 star transits.

As part of the plan to improve the time service, an atomic frequency was installed as the control element for the time signals. Also, the 7,335-kHz channel of CHU was improved with a new transmitter operating into a vertical antenna. The time laboratory acquired a second caesium resonator to serve as standby. Time may now be resolved to one tenth of a microsecond. Comparison by means of the Flying Clock Experiment conducted by the Hewlett Packard Company of California indicates that the atomic clocks at Ottawa and Washington will drift apart one thousandth of a second in about 40 years if they maintain their present rates.

Engineering plans have been completed for the establishment of a prairie network of automatic-camera stations for a meteorite observation and recovery (MORP) program. The first station will be established near Saskatoon early in the new year. The Meanook-Newbrook (25-mile baseline) observatory has continued to secure unique photographic records of meteors and their spectra which yield information concerning their space trajectories and their chemical composition.

Extensive film records of solar-image definition were obtained on Mt. Kobau, B.C., for a period of six weeks in mid-summer. The films are being used to evaluate the quality of daytime observing conditions at this site. Engineering plans for a new solar spar telescope, to be located near Ottawa, have been completed and most of the component optical parts acquired. The spar is an equatorially-mounted platform that will carry several refractor telescopes for simultaneous time-lapse photography of active solar regions in different wavelength bands. The spar telescope will be used to detect transient events in the solar atmosphere, particularly those events that affect the Earth-Sun environment.

In addition to the solar site-testing on Mt. Kobau, efforts have been directed to the establishment of two telescopes. The one is a Polaris Image Monitor which is designed to track Polaris accurately and will measure the fluctuations in brightness and position caused by atmospheric turbulence. The other is a 16-inch reflector which will be used for

photographic and photoelectric photometry. Both of these telescopes will give valuable information concerning the properties of the Mt. Kobau site.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY, PENTICTON, B.C.

This observatory operates three major radio telescopes – a conventional 84-foot "dish", tuned to 1,420 MHz, and two arrays operating at 22 MHz and 10 MHz respectively. It is in process of designing a "super-synthesis" telescope, which will consist of two "dishes" mounted on railway lines in such a way that the distance between them can be accurately varied. One of the 8.5-m paraboloids for this telescope has been mounted and equipped with receivers. Work on the phasing cables, feeder systems and spectrometer is proceeding at University of British Columbia. Soil tests have been made for foundations of the rail lines. Engineering studies are under way to design the track and bogies for the two antennas.

Another development going forward is an attempt to produce a display for an array-type radio telescope which will show a two-dimensional picture of the sky. The techniques involve ultrasonic waves and a laser beam. Preliminary experiments have produced a spectrometer and an interferometer synthesizer. It is hoped that this technique will permit operation of low-frequency instruments in the presence of man-made interference.

The routine programs of the Observatory include the following:

(1) A catalogue of accurate fluxes for 180 sources has been prepared with the 22-MHZ telescope. Observations now use beam scanning over a small range in declination.

(2) The new 10-MHz receiver system has been used for improved mapping of the regions around several deep absorption features. Comparisons with both 22-MHz results and high-frequency data will yield information on the physical conditions in ionized-hydrogen regions.

(3) Observations for the 1,420-MHz continuum survey are almost complete over the entire visible sky. A catalogue of 615 radio sources has been published, giving important statistical properties of radio sources. A few tens of radio sources not previously catalogued have been discovered.

(4) A survey of neutral hydrogen in the galazy is providing data on the kinetic temperature of the gas and differential rotation at high galactic latitude.

There have been a number of cooperative ventures with other groups. Close cooperation is maintained with radio astronomers at the University of British Columbia who, as mentioned earlier, are cooperating in instrumental development. A joint experiment with the University of Calgary succeeded in detecting radio pulses from cosmic-ray showers at 22 MHz. The most exciting cooperative work has been in the "Long Baseline Interferometer" in which the NRC radio telescope in Algonquin Park and the telescope at Penticton, 3,000 km apart, were effectively worked in unison to obtain measurements of the angular diameters of eleven quasars. This experiment involved the cooperation of many groups.

Early in 1968 it was announced in Cambridge that four rapidly pulsing radio sources had been discovered. This may perhaps be one of the most important astronomical discoveries of the decade. These sources, though weak, have been observed at 113 MHz.

DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B.C.

As a result of new instrumentation developed for the spectrographs attached to the 72-inch and 48-inch telescopes and put into operation during the year, new, far-reaching observational programs are being undertaken by the scientific staff and results important to the astronomical community are expected. On the 72-inch telescope an off-axis spectrograph with an f/5 camera, using gratings giving dispersions of 15 A/mm and 60 A/mm, has been installed. The efficiency relative to the former prism spectrographs has been increased by a factor of four, and with the higher dispersion 8th-magnitude stars can be photographed in about an hour, while with the lower dispersion 11th-magnitude stars are now within reach. In addition, programs involving stars which vary rapidly in light and in spectrum and therefore require good time resolution can now be launched. The Observatory has been studying the structure of the galaxy by the analysis of spectra of the hot stars for more than forty years. These programs will now be extended to fainter stars, but because of the large number of stars involved, details concerning the observational programs have not yet been decided. On the 48-inch telescope a large mosaic grating, made up of four separate six-inch gratings, has finally been commissioned for the coude spectrograph; the only other similar instrument now in use is attached to the 200-inch telescope on Mt. Palomar. An image slicer, the design for which has been patented recently, has also been installed on this spectrograph. This device uses multiple reflections and directs starlight, formerly wasted, into the spectrograph. It was made possible through the development of high-reflectance coatings for the mirrors, but it also uses a concept not formerly considered for astronomical spectroscopy. With these new improvements, an almost fourfold gain of speed has been achieved for the coude spectrograph, and sixth-magnitude stars can now be photographed at the highest dispersion (2 A/mm) in a few hours. The analysis of several peculiar stars, both hotter and cooler than the sun, is now being made with some of these spectra. The staff was brought up to its full complement during the year with the appointment of two research scientists and a scientific officer.

A few of the important results obtained from analyses of the observations made here include: Statistical studies of spectroscopic binaries indicate that there may be two principal groups of stars in the solar neighbourhood with different characteristics as related to their mass and absolute luminosity; additional studies of stars in the Hyades cluster are being made to test this relation. Investigations of eclipsing stellar systems reveal rather large differences between the diameters of giant stars as calculated from the length of eclipse and from theoretical formulae linking temperatures with radii; the problem may be related to uncertainties in our knowledge of the distribution of energy in these stars in regions cut off by the earth's atmosphere. Plates of 1967 Nova Delphini are being measured to study motions in the expanding shells created by the nova outbursts; this nova is quite unusual because it has remained close to its maximum brightness for many months and also because there have been rapid changes in the velocities observed in the spectrum from day to day. Even more rapid changes were observed with the new photoelectric spectrum scanner in the spectrum of the newly-discovered variable star CH Cygni. A new study of stellar associations has shown that Petrie's calibration relating the luminosity of a star to the strength of its hydrogen lines requires a correction of -1.3 magnitudes for the very hottest stars. In the field of theoretical investigations, the evolution of hot main-sequence stars with masses between 7½ and 15 times the sun has been followed until their hydrogen has become exhausted.

During the year the 72-inch telescope was used on 175 nights and the 48-inch telescope on 164 nights with a total of 1,248 hours of usable clear sky – rather more than the average over the past ten years and nearly equal to the average of the 50 years of observing at Victoria.

SEISMOLOGY DIVISION, OTTAWA

A new seismic observatory was commissioned at Churchill, Man. The seismic station operated at Fanshaw Dam, London, Ont., was closed down because of rapidly worsening environmental effects and replaced by a more modern local seismic station at Sudbury, Ont., operated in cooperation with Laurentian University. The total number of seismic stations operated by the Department remains at 23, complemented by four second-order local stations.

A major extension of the strong-motion network in western Canada for earthquake engineering continued: 14 stations are now fully equipped and 57 locations have been instrumented with seismoscopes for detailed ground-acceleration studies.

Calculations were completed for the preparation of a new earthquake-zoning map for Canada for the National Building Code definition of earthquake loads. These calculations use all the researched data accumulated on Canadian earthquakes to 1963. The quantitative ground-acceleration estimates have been examined by the National Committee for Earthquake Engineering and form the basis for the code revision, which will be implemented in 1970. Some details require final resolution with the engineering profession, but the general proposals of the Division have been adopted by the appropriate authorities.

No major earthquakes occurred in Canada during the year, but a number of minor shocks were felt in both eastern and western Canada. Research studies of microearthquakes continued, and a number of seismic regionalization studies were published.

Quantitative earthquake-risk estimates were given to engineering and insurance companies; an increase in demands for advice was noticeable for large engineering works and other critical structures.

International cooperation in the study of earthquakes and the dissemination of readings and records to international and national research agencies and workers continued at a high level. There was an increase in the machine-compatible data flow.

A seismic-array-processing laboratory was brought into operation in Ottawa, employing a small general-purpose "in-house" digital computer with considerable peripheral equipment. The "in-house" capability for the data-processing of array magnetic tapes has proved an outstanding success, and a number of fundamental papers have been published on array seismology and detection and identification problems.

Other seismologists have continued research into the mechanism of earthquakes, into surface-wave dispersion and into the mantle-core transitional zone, deep within the earth. A large body of results has been published from experimental and theoretical studies of the character of seismic body-wave arrivals.

The crustal-seismic-refraction group completed a major experiment on the ice northwest from Prince Patrick Island, N.W.T. A profile some 200 km long was shot with the use of three field parties and 20 large shots. Later in the year six explosions in a lake on southern Vancouver Island were recorded by six moving field parties in British Columbia. This work successfully reversed an earlier profile. Finally, in cooperation with the University of Alberta, four large explosions were detonated near Revelstoke, B.C., to test for deep faulting in southern Alberta. A critical analysis of the 1965 Hudson Bay

experiment was submitted for publication, and the reduction and interpretation of data for the major experiment of 1966 was considerably advanced during the year under review.

The heat-flow section drilled four holes in northern Ontario across a major geophysical feature. Measurements were made in eight provinces as part of the continuing study of approximately forty active sites, well distributed throughout Canada. Probe measurements were made from the ice in the western Arctic and an unsuccessful attempt was made to obtain data in Great Slave Lake. Laboratory and theoretical studies continue on the feasibility of making quicker, cheaper but still useful determinations of heat flow through lake bottoms. The first interpreted values from the heat-flow field program were published.

GRAVITY DIVISION, OTTAWA

Work on the unified adjustment of all gravimeter-control-station ties in Canada began in 1967. During the year four computer programs were developed to process, plot, edit, and adjust control-station operations. Analyses of the performance of four LaCoste meters were made and a field evaluation of the rebuilt Canadian pendulum apparatus on the North American Calibration Line was successfully completed.

The reduction of data for the Canadian contribution to the First Order World Gravity Net consisting of some 1,000 gravimeter measurements in Canada, Europe, the United States, South America, Australia, and the Western Pacific is now under way. When the gravimeter measurements of other agencies become available the Division will participate with the 1381st Geodetic Survey Squadron (GSS) USAF in a joint program to adjust the First Order World Gravity Net. The computer program developed for the Canadian Net will be used in this project with additional routines for statistical analysis of the results contributed by the 1381st GSS. The Canadian and American data have now been converted to a common format and preliminary editing runs have been carried out on Canadian government computing facilities. The final adjustment of the net has been tentatively scheduled for September, 1968.

During 1967, all gravity data collected by the Division up to December, 1966, were compiled to produce a new Gravity Map of Canada (in four sheets) at a scale of 1:2,500,000. The map passed the colour proof stage and was scheduled for printing in May, 1968. The map will also be available at a scale of 1:5,000,000.

As in previous years, a full program of field measurements was carried out. Investigations were made as follows:

(1) A regional gravity survey was made in northern Alberta and adjacent areas of British Columbia and the Northwest Territories, covering an area of some 225,000 square miles.

(2) The gravity survey of British Columbia and the adjacent coastal waters was continued. Stations on land (284) and under water (316) were observed on Queen Charlotte Islands, Vancouver Island and on the mainland as well as in Hecate Strait and Queen Charlotte Sound. The results of these surveys have been corrected for terrain with computer programs developed in the Division.

(3) Gravity surveys were again extended over the Arctic Islands during 1967. Measurements were made on Devon and Ellesmere Islands, and over the Arctic Ocean in the vicinity of Prince Patrick Island.

(4) The underwater gravity survey of the Gulf of St. Lawrence was completed apart from a small part of the Strait of Belle Isle.

(5) More detailed local surveys were made over granite batholiths in the Burleigh-Anstruther area of Ontario and over the Morin anorthosite body in Quebec.

(6) A highlight of the field program occurred in May 1967 when scientists of the Division led a joint Canada-USA scientific expedition to the North Pole. The party flew from Alert to a camp on the ice pack within 20 miles of the Pole and remained on the ice floe for eight days, during which they took gravity and hydrographic measurements for geodetic purposes and sun and star shots to determine the position of the ice camp. The navigational data were relayed by amateur radio to a computer in Minneapolis and the computed results returned to the party via the same route within two hours. In addition, a sonar device was dropped on the ocean floor to study in detail the movement of the Arctic ice pack and to investigate the possible use of such devices for local navigation. This sonar device will be used in various geophysical experiments proposed for the next three years.

Interpretational studies of the regional gravity anomalies in the following areas have been completed during the year or are nearing completion: Hudson Bay, northern Saskatchewan, northern Manitoba, Quebec, Newfoundland, Appalachia (a review), Somerset and Prince of Wales Islands. Studies of the following areas are in progress: Quebec, Anstruther area, Bear and Slave Geological Provinces, Gulf of St. Lawrence, Queen Elizabeth Islands, and the Ontario-Quebec Mining Belt.

The continuing search for possible ancient meteorite craters in Canada has led to the investigation of six craters by diamond drilling, 12 by gravity surveys, eight by magnetic and six by seismic methods. Recent work has been largely concerned with the Brent, Deep Bay, West Hawk Lake, Lac Couture, Pilot Lake, Nicholson Lake and La Malbaie craters with further analysis of data from the New Quebec, Clearwater Lake, Carswell and Manicouagan craters also in progress.

The earth-tide observatory is now in operation in an old asbestos mine north of Ottawa. The purposes of the studies are: (1) to extend the existing coverage of continuous, systematic observations of earth tides; (2) to investigate the reliability of microgravimetric instruments and the techniques of site selection and installation; (3) to investigate the utility of these measurements in regional studies of the earth's crust and mantle.

The first phase of a long-term program to determine possible vertical movements of the crust due to loading by water at the South Saskatchewan River Development Project dam site was begun in 1966 by the Division. About 45 observations were made in the vicinity of Elbow, Sask. In 1967 unclosed portions of the control network were closed and a primary network linking Saskatoon, Moose Jaw and Swift Current to each other and to Elbow near the dam was established. In a similar survey 75 stations were established at the W.A.C. Bennett Dam on the Peace River.

GEOMAGNETISM DIVISION, OTTAWA

In order to keep the magnetic charts of Canada up to date, the slow changes in the direction of the geomagnetic field are determined by making careful measurements every few years at each of 100 repeat stations, uniformly distributed over the country. During 1967, 21 repeat stations were occupied, in Quebec, Ontario, Newfoundland and the Maritimes.

Reduction of the absolute values from the 1965 three-component airborne magnetic survey was completed, and the results were distributed to world data centres and map-making agencies in several countries. The survey covered Greenland, Iceland, and the

four Scandinavian countries, and intervening ocean areas. The survey data have now been digitized at three-kilometer intervals, and interpretation of detailed results in terms of crustal structure has been started.

Time variations of the geomagnetic field were recorded continuously at nine magnetic observatories: at Alert, Mould Bay, Resolute Bay, and Baker Lake, all in the Northwest Territories; at Great Whale River, in northwestern Quebec; at Churchill, Man.; at Meanook, Alta.; at Victoria, B.C.; and at Agincourt near Toronto. Buildings were completed for two new magnetic observatories – at St. John's, Nfld. and Ottawa; they were to begin operation in April, 1968. The Ottawa observatory will replace the Agincourt observatory which must be abandoned because of increasing industrial interference.

Construction was completed of the new geomagnetic laboratories on a 200-acre site in the Green Belt, 10 miles east of the centre of Ottawa. The complex consists of a main building, containing instrument-development laboratories, darkrooms, offices, and a machine shop, and 15 small isolated buildings of non-magnetic construction. It includes the new Ottawa magnetic observatory, mentioned in the preceding paragraph. It provides improved facilities for research in rock magnetism and instrumentation, both for the Observatories Branch and for the Geological Survey of Canada, and will permit more effective training of personnel for observatory and field work.

Three field programs were carried out to investigate electric currents induced in the crust and upper mantle of the earth by natural geomagnetic variations, in southern and central British Columbia, on Ellesmere Island, and in south-western Quebec. Arrays of portable observatories recording magnetic variations and the corresponding earth currents were operated in a line for several weeks. After a few moderate magnetic disturbances were recorded, the portable stations were moved to new sites. Analysis and interpretation of the data is proceeding well, and some results are already in press.

Studies of the natural magnetization of sedimentary rocks from the Maritime Provinces were continued. Many valuable results were published covering most of the Upper Paleozoic – a period for which previously there had been very few North American paleomagnetic results. An important new technique of interpretation was developed for rocks which contain two superimposed magnetizations in different directions.

Polar Continental Shelf Project

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Arctic coast of Canada, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Arctic Archipelago and the waters between them, and other areas that may be of special interest. The Project serves in part to facilitate the Arctic researches and surveys of other units of the Department of Energy, Mines and Resources; in part it carries out, with its own personnel, work that is unique within the Department; it also serves as the vehicle through which the investigations of other government agencies are carried out in the Arctic Archipelago and Arctic Ocean, and it provides facilities and support for approved university researches in the area.

In 1967 the field activities of the Polar Continental Shelf Project ranged from the North Pole to the Mackenzie River delta, with some associated activities in southwestern Yukon and the Canadian Rockies. The main base of Arctic field operations was at Mould Bay on Prince Patrick Island, with a secondary base at Alert on Ellesmere Island. About

105 persons were engaged in the field work, which involved three departments of the Canadian government, one provincial government, two agencies of the United States government, and six university or private research groups.

The Canadian Centennial flag was flown by the Project's field party in the vicinity of the North Pole, and, as an international gesture, the flags of all the nations participating in Expo '67 were fastened to a sonar marker that was dropped onto the ocean floor, 25 miles from the North Pole.

The major activities comprising the 1967 program of the Polar Continental Shelf Project were:

Aeromagnetic Surveys. Measurements of the total magnetic field as recorded from a height of 1,000 feet above the surface were made over the continental shelf and continental slope, southern Prince Patrick Island, Fitzwilliam Strait, Crozier Channel, Eglinton Island, and M'Clure Strait. The surveys are part of the aeromagnetic survey of Canada undertaken by the Geological Survey of Canada. Approximately 15,000 line miles were flown, providing information for mapping an area of 27,000 square miles on a scale of 1:250,000.

Geodetic and Topographic Surveys, Position Determination and Control. Tests were made at Mould Bay of a new method of determining geodetic positions with improved accuracy, using computer analysis of astronomic observations. This method was then employed in the vicinity of the North Pole in conjunction with a local gravity survey and study of ice drift, to obtain information on the configuration of the geoid near the Earth's axis. A sonar transponder was placed on the ocean floor at Latitude 89°35′56″N Longitude 113°43′53″W to serve as a fixed reference for these and future studies.

The precise survey of a geodetic triangulation network between Ellesmere Island and northwestern Greenland was completed. It is intended that this network will be resurveyed in ten and twenty years' time to check on possible crustal movements in the area.

The Polar Continental Shelf Project played a part in organizing and supervising the repeated aerial photography and the ground survey of the surging Steele Glacier in the St. Elias Mountains of southwestern Yukon. The work included low-level oblique photography of the lower part of the glacier during the winter and spring, through the co-operation of the (then) Water Resources Branch, and repeated vertical aerial photography of the entire drainage basin during the summer, through the co-operation of the Surveys and Mapping Branch, with ground control provided through the co-operation of the Army Survey Establishment.

Marine Geology. Samples of bottom sediments were obtained offshore from channels between Prince Patrick Island and Melville Island, and in the inlets of western Melville Island. Collections were made of the material presently being delivered to the sea by the rivers of Melville Island. These activities are part of a continuing program to determine the age, source, and conditions of sedimentation on the floor of the seas surrounding the islands of the archipelago and covering the continental shelf and continental slope, and to provide evidence for changes of sea level and variations of climate in the geologically recent past.

Geomagnetism. A study was made of the geomagnetic character and behaviour of parts of north-central and eastern Ellesmere Island, where there are indications of crustal

peculiarities, such as enhanced electromagnetic conductivity, that may be connected with a major geological structure separating Ellesmere Island and Greenland.

Glacier Physics and Glaciology. Routine glaciological measurements were continued on the Meighen and Melville Island icecaps.

Further measurements were made of glacier temperatures and deformation in boreholes on Athabasca glacier, Alberta, as part of a continuing study of the mechanism of ice flow.

Gravity. The gravity investigations of the Polar Continental Shelf Project are carried out in co-operation with the Gravity Division of the Observatories Branch. The regional gravity survey was continued over the continental shelf and continental slope offshore from Prince Patrick Island, the Lincoln Sea and nearby parts of northern Robeson Channel, in a small area near the North Pole, and over northern Devon Island and southern Ellesmere Island.

Some gravity observations were made on surging Steele Glacier, and on nearby "Fox glacier" in the St. Elias Mountains, Yukon.

Heat Flow. Measurements of the flow of geothermal heat from the ocean floor were continued off Prince Patrick Island and in Crozier Channel.

Hydrographic Survey. The bathymetric survey of the continental shelf and slope, and of the straits and sounds between the western Queen Elizabeth Islands, was continued, with through-the-ice sounding on a grid spacing of 7 to 10 kilometres over about 35,000 square kilometres of the Arctic Ocean offshore from Prince Patrick Island. This work will be published at a scale of 1:500,000.

The hydrographic survey of northern Robeson Channel and Lincoln Sea, with soundings at intervals of about 4 kilometres, was completed to approximately Latitude 84° 00′N, Longitude 53° 00′W. This survey has covered approximately 32,000 square kilometres in an area of very heavy sea ice at the entrance to one of the major passages between the Arctic and Atlantic Oceans. The soundings were carried out by helicopter.

Oceanography. Field support and equipment were provided for an oceanographic reconnaissance of the Lincoln Sea. This work was undertaken by the Marine Sciences Centre of McGill University as part of the study of the "North Water" phenomenon of northern Baffin Bay.

Sea-Ice Studies. Systematic patrols were made of all major waters of the Queen Elizabeth Islands and of the adjacent Arctic Ocean and Parry Channel, throughout the season of significant sea-ice activity. Information was collected on the nature, break-up, amount, distribution, dispersal, and formation of the sea ice and of certain tabular icebergs or "ice islands."

Distinctive markers, in easily recognizable patterns, were set up on a number of tabular icebergs or "ice islands" in the Arctic Ocean off M'Clure Strait and in the Lincoln Sea to aid in identification and tracking by radar and visual means. The movement of these bodies is being followed through observations of Canadian and U.S. patrol and observation agencies, and is providing evidence of the rate and patterns of ice drift.

During the occupation of the geophysical and hydrographic camp on the Arctic Ocean ice, 200 kilometres offshore from Prince Patrick Island, a continuous record of the

drift of the ice pack was kept by means of the Decca Lambda survey equipment. Meteorological observations were also recorded. This is the first time that it has been possible to obtain detailed information on the movement of the ice, and its relation to the weather, in the unrestricted ocean for an extended period.

Seismic Studies. A seismic refraction traverse across the continental shelf and continental slope was run from Houghton Head on southwestern Prince Patrick Island, extending about 350 kilometres out to sea. The information obtained should add to our knowledge of the crustal and geological structure of the west edge of the Sverdrup sedimentary basin, the continental shelf, and the border of the Arctic Ocean basin.

Other Activities. Support was provided to a project of the Province of Quebec and the University of Alaska, in which muskoxen were obtained on Ellesmere Island for establishment of a breeding herd near Fort Chimo on Ungava Bay.

Assistance was given to a party from the Department of National Defence making an archeological and geomorphological reconnaissance along the north coast of Ellesmere Island.

Specimens of fossil vertebrates were collected for the Natural History Branch of the National Museum of Canada.

Some assistance was provided for university and private investigations in physiography, acarology, ornithology, geology, and history.

MINERAL DEVELOPMENT GROUP

Mineral Resources Division

The Mineral Resources Division conducts fundamental and applied resource-engineering-economic research and field investigations into non-renewable resource problems, policies and programs, on a regional, national and international basis. The work covers all aspects of the mineral industry from resources through exploration, development, production, processing, transportation, and consumption. On the basis of this work, the Division prepares economic forecasts and appraisals of the Canadian mineral economy, publishes resource-engineering-economic reports, and advises government departments and agencies on non-renewable resource policy matters.

Since July 1966, the Resource Administration Division has been a part of the Mineral Resources Division and has had the responsibility of administering and managing the federal interests in mineral resources off Canada's west and east seacoasts and in Hudson Bay, as well as those federally-owned mineral rights in the provinces that become available for disposition. As part of its responsibilities, this group helps to ensure that other interested governmental agencies are aware of proposed offshore exploration and that operators are in turn aware of any special requirements of these agencies. The group is also involved in a wide range of policy considerations of national and international import associated with matters relating to offshore resources.

ADVISORY AND CONSULTING SERVICES

The Mineral Resources Division provided other government departments with analyses and advice on mineral developments so that assessments could be made of the need for public services such as roads, airstrips, docks, housing, manpower training, etc. in specified areas. A subsidiary but important aspect of this activity is the provision of information and advice on mineral economic matters to consultants and company representatives, through office interviews and/or correspondence. Representative of the type of advisory service provided were the following:

Regional Studies in Eastern Canada. A detailed report *Mineral Resource Development, Province of New Brunswick* was prepared during the year at the request of the Atlantic Development Board. This report was similar to one completed in 1966 on the Province of Newfoundland and Labrador, and made available by the Atlantic Development Board to the Royal Commission on the Economic Prospects of Newfoundland and Labrador. The New Brunswick report reviews in depth the province's mineral industry. It contains an appraisal of the possible course of future mineral developments including production, capital investment and employment trends, and what direction assistance by the provincial and federal governments might take to speed that development. A similar study in Nova Scotia was commenced at the request of the Atlantic Development Board and is expected to be completed during the summer of 1968.

Northern Development. The Division acts in an advisory capacity to the Department of Indian Affairs and Northern Development and, in this connection, a special study was

completed for an interdepartmental committee concerning Canadian access requirements to tidewater on the Pacific Ocean. The study included a detailed examination of the existing mining industry, a regional mineral-potential appraisal, transportation requirements, a water-resource analysis, and an examination of the physical aspects of access to tidewater. During the year, a major study was made for the Department of Indian Affairs and Northern Development on the Baffinland iron-ore project on Baffin Island. In connection with this project, members of the Division also made an analysis of market conditions for iron ore. Petroleum-exploration opportunities in the Arctic were also reviewed during the year, in relation to industry's current expansion plans.

St. Lawrence Seaway Study. Officers of the Division prepared for the Department of Transport a detailed study *Iron Ore Requirements and Sources of Supply in the Great Lakes Area of Canada and the United States to 1980.* The study took into account the expected growth of the steel-producing areas in the Great Lakes area; available sources of supply of iron ore and their economic competitiveness; and the captive nature of sources of iron ore available to the area. Transportation costs, production costs and Seaway tolls were also reviewed, along with technological changes that are affecting the demand for iron ore.

Kennedy Round of GATT Negotiations. The Kennedy Round of trade negotiations under the General Agreement on Tariffs and Trade (GATT) ended June 30, 1967. Canada received tariff concessions from other countries and gave concessions in return.

The Department was represented by a senior officer on the Canadian Tariffs and Trade Committee, set up in 1964 to prepare for the negotiations, and also on the negotiating team at Geneva. The Mineral Resources Division provided the necessary support services, assisted in the evaluation of briefs from industry, and in the study of intra-governmental proposals in the field of minerals, metals and related semi-fabricated products. The Division also prepared assessments of mineral-industry needs and problems and made recommendations on the mineral content of the Canadian offer.

Taxation. Analyses and recommendations were provided to the Department of National Revenue with respect to tax benefits under the Income Tax Act which are applicable to the mineral industry. Reports were prepared on twenty-one applications for three-year tax exemptions, one application for the special oil-pipeline depreciation allowance, and three applications for research grants under the Industrial Research and Development Incentive Act.

A small number of studies were made during the year relative to the report of the Royal Commission on Taxation and the implications of the commission's recommendations for the Canadian mineral industry. Some of the most important and far-reaching recommendations of the commission relate to the taxation of mineral enterprises.

Nickel. An officer of the Division is a member of an interdepartmental committee formed to assist in the allocation of nickel to Canadian consumers. During the current nickel shortage, Canadian consumers have been limited to the amount of their 1966 purchases from domestic suppliers. This system threatened to cause hardships for certain consumers, and the committee is reviewing requests for increased quotas and may make recommendations that justified needs be satisfied by the three domestic producers.

The Maritime Coal Industry. The Division has helped to develop a new policy for the Nova Scotia and New Brunswick coal industries.

As a result of certain federal-provincial agreements, the Cape Breton Development Corporation was formally established on October 1 and charged with the rationalization of coal mining in the Sydney-Glace Bay area of Cape Breton Island as well as the simultaneous encouragement and development of new industry on that island. Formation of the new corporation proceeded throughout the second half of the year, along with essential work on the acquisition of the Dominion Steel and Coal Corporation coal mines. With coal-mine employees numbering 6,500, federal coal subsidies for Nova Scotia at $31 million per year, the major operator intending to withdraw from coal mining, intensified competition from other fuels, and a limited life expectancy for the mines, the Cape Breton coal problem had reached crisis proportions and aroused national concern. The program developed for Cape Breton Island marks the commencement of a new and interesting approach to the problems of a declining mining community.

Simultaneous discussions with the Province of New Brunswick, where the Minto coal field was faced with a situation similar to that of the Sydney coal field, led to the conclusion on March 26, 1968, of an agreement between Canada and New Brunswick on a new policy for New Brunswick coal. Under this agreement, New Brunswick will seek to rationalize mining and stimulate industrial development. The concept is similar to that for the Nova Scotia industry.

Frontier Package Television. Officers of the Division assisted the Canadian Broadcasting Corporation in its choice of communities which should receive priority in the installation of facilities to handle packaged television programs on a regular schedule. This service is designed to assist in the attraction and retention of workers in isolated locations.

INTERNATIONAL ACTIVITIES

An officer of the Division continued to represent the Department on the Canadian delegation to the International Lead and Zinc Study Group, and attended the group's 11th session, held in Geneva in October 1967.

The Division continued to review international trade in tin and Canada's position as a tin consumer under the Third International Tin Agreement. Division staff also compiled extensive statistics on the Canadian iron and steel industry for the OECD Special Committee for Iron and Steel. A representative of the Division attended three meetings of the committee in Paris. The Division also supplied data to two other OECD groups – the Special Committee for Non-Ferrous Metals, and the Nuclear Energy Agency. The latter consisted of reports, prepared in collaboration with Eldorado Mining and Refining Limited, on Canadian uranium reserves and potential productive capacity.

Statistics were also supplied to the Iron and Steel Committee of the United Nations Economic Commission for Europe. A representative of the Division attended committee meetings in Geneva. The Division continued its contributions to the study on the world supply and demand for tungsten, conducted by the United Nations Tungsten Committee, and an officer of the Division attended a meeting on this subject. Another officer took part in a trade mission to Eastern Europe exploring the possibilities for exporting Canadian minerals and metals to "Iron Curtain" nations.

PUBLICATIONS

The Division published reports in the *Mineral Information Bulletin* series on copper and iron ore, along with its regular preliminary annual review of the Canadian mineral industry. Also completed were nine *Operators Lists,* the 1965 *Canadian Minerals Yearbook* and the seventeenth edition of the popular Map 900A *Principal Mineral Areas of Canada.* Work proceeded on reports on berylium, zinc, manganese, natural gas, and fertilizers and on a gas-pipeline map. Several papers were prepared and delivered at national and international conferences or for publication in technical journals. The Division has a continuing program of educational mineral filmstrips. During the period, work continued under the direction of commodity officers on the two filmstrips, iron and steel and aluminum, designed for use in high schools. Both filmstrips will be in kit form with supporting information and samples. The Division's photographic library and mineral-resource records centre continued to be strengthened.

A major report on the Canadian and world uranium industry, which had been in preparation for a number of years, was published during the year; it is entitled *The Uranium Industry, Its History, Technology and Prospects.* At a period when the Canadian uranium industry is preparing itself to meet the needs of an expanding commercial market for uranium in the field of nuclear power, the report provides a timely review of the industry, its technology, and opportunities for the future.

The sixth edition of the *Digest of the Mineral Laws of Canada* was published during the year. The *Digest* is a summary of the Acts and Regulations in effect in Canada in 1965 and 1966 with respect to disposition of rights, conservation rules, fees, mineral taxation and royalties, and bounties and subsidies concerning minerals.

Work was completed on a comprehensive resource report on nickel. The report emphasizes the resource-economic aspects of the nickel industry and will complement the International Nickel Company of Canada Limited book *The Winning of Nickel* – an in-depth study of the technical aspects of the industry. It includes chapters on: history, ore deposits and resources; exploration; mining; processing; commercial forms, properties and uses; Canadian primary industry history, corporate structure, operations, production potential, position in the economy; foreign primary industry; and world supply and demand. It is expected that the report will be available for distribution in the fall of 1968.

FOREIGN AID TRAINING

The Division, on behalf of the External Aid Office, arranged 25 technical training programs for foreign trainees and provided consultation on 11 additional applications. These programs were sponsored mostly by the Colombo Plan and took place in the Department of Energy, Mines and Resources as well as in private industry. Thirty trainees completed training programs during the fiscal-year period ending March 31, 1968. At the end of the period six trainees were on study courses and seven planned programs were awaiting arrival of candidates. In addition to these postgraduate training programs, a number of foreign undergraduate students attending Canadian universities were helped to find summer employment and surveying instruction. The Division also participated in arrangements to send mineral consultants abroad to advise certain developing countries on mineral policies and projects.

MINERAL OCCURRENCE INDEX

The Division maintains an index of Canadian mineral occurrences available for the use of anyone interested in mining and mineral exploration in Canada. The index consists of comprehensive summaries of available information on some 10,000 mineral occurrences, with provision for revisions and additions as required. These summaries, each on individual cards, are arranged in conformity with areas of the National Topographic System in a manner which enables information on any occurrence or area to be readily located.

In May 1967 an agreement for the exchange of mineral occurrence information was reached with the Department of Mines and Petroleum Resources, British Columbia, complementing agreements ratified in 1961 with the Nova Scotia Department of Mines, and in January 1967 with the Ontario Department of Mines.

The indexing of Canadian mineral occurrences was begun before 1900 and was carried on intermittently for a number of years. During the past ten years indexing has been continuous.

ROADS TO RESOURCES

The Roads to Resources Program is a national program designed to provide access to areas potentially rich in natural resources. The administration of the agreements, which provide \$7.5 million as the federal share for each province, was transferred to the Mineral Resources Division in October 1966.

Federal payments to March 31, 1968, were approximately \$73.3 million. The balance, some \$1.7 million, has been committed for the completion of the program in 1969-70.

Province	*Number of Roads*	*Mileage Completed*	*Federal Contributions to March 31, 1968*	*Termination Date*	*Status*
Newfoundland	10	270.78	6,403,577	March 31/70	–
Prince Edward Island	30	425.9	7,500,000	March 31/68	Completed
Nova Scotia	16	356.3	7,488,792	March 31/66	Completed
New Brunswick	20	271.1	7,441,956	March 31/69	–
Quebec	3	179.0	7,500,000	March 31/67	Completed
Ontario	8	281.6	7,500,000	March 31/69	Completed
Manitoba	5	338.8	7,500,000	March 31/67	Completed
Saskatchewan	6	455.6	7,468,100	March 31/68	Completed
Alberta	2	415.9	7,500,000	March 31/67	Completed
British Columbia	1	213.0	7,500,000	March 31/68	Completed

ADMINISTRATION OF MINERAL RIGHTS

Canada Oil and Gas Permits. Offshore Canada Oil and Gas Permits are valid for six years with six renewals of one year each. A permit must be converted to oil and gas leases before commercial production can be undertaken. There are no leases in the offshore areas as yet.

A total of 295 Canada Oil and Gas Permits covering 19 million acres were issued in offshore areas during the past year, as follows:

East coast	–	253 permits	–	17,110,323 acres
West coast	–	18 permits	–	822,674 acres
Hudson Bay	–	24 permits	–	1,378,372 acres

This brought the number of offshore Canada Oil and Gas Permits (except the Arctic coast) to 2,976, covering 220.5 million acres, as follows:

East coast	–	1,904 permits	–	151,322,138 acres
West coast	–	246 permits	–	15,174,486 acres
Hudson Bay	–	826 permits	–	54,021,908 acres

On March 31, 1968, the Division held approximately $15 million in the form of guaranty deposits made by permittees against the work requirements of their holdings. The total revenues received during the fiscal year 1967-68 on behalf of offshore permits, including permit fees, transfer fees, forfeitures, maps and exploratory licences, amounted to $101,451.89, most of which was derived from permit fees.

Mineral Claims. Offshore mineral claims are issued for mineral rights other than oil and gas rights. Each mineral claim covers an area not greater than 1,500 feet square (approximately 52 acres). A total of 105 offshore mineral claims were recorded during the past year off the east coast. This brought the total number of mineral claims to 351, distributed as follows: east coast, 161; west coast, 105; Hudson Bay, 65. Total revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1967-68 amounted to $943.97.

Federal Lands in the Provinces. During the past year, 86 oil and gas leases were issued for lands in this category; of these 13 were in Alberta,41 in Saskatchewan, 31 in Manitoba, and 1 in Ontario. This brought the total number of federal oil and gas leases in the provinces to 286 as follows: 111 in Alberta; 103 in Saskatchewan; 58 in Manitoba; 5 in Ontario. In addition, there are 5 gas leases and 4 oil leases in Alberta. There are also 3 leases for minerals other than oil and gas – 2 in Ontario and 1 in Saskatchewan. On March 31, 1968, the following numbers of oil and gas leases were productive: 37 in Alberta; 19 in Saskatchewan; 6 in Manitoba; 1 in Ontario. The total revenues received during the fiscal year 1967-68 on behalf of oil and gas leases, including royalties, lease-sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $282,499.61, most of which was derived from royalties.

THE EMERGENCY GOLD MINING ASSISTANCE ACT

The application of the Act was extended on December 21, 1967, for three years to the end of 1970 without change in the formula for computing the amount of assistance payable.

The Act was introduced in 1948 to provide the operators of marginal gold mines with financial assistance in meeting rising costs of production. The assistance has extended the operating life of many gold mines and has thereby allowed the communities dependent upon them to adjust gradually to diminishing economic support.

An amendment to the Act in 1963 contained a restriction limiting eligibility for assistance in the case of lode gold mines commencing production after June 30, 1965, to

those providing direct economic support to an existing mining community. A gold mine is deemed to provide such support if more than 50 per cent of the persons employed at the mine reside in the established mining communities listed in a schedule to the Act.

The administration of the Act is carried out in the Mineral Resources Division under the direction of the Assistant Deputy Minister (Mineral Development). Gold mines receiving assistance are visited by inspection engineers from the Division who determine the proper classification. The Audit Services Branch, Office of the Comptroller of the Treasury, examines interim applications and carries out the final audit of each applicant's books of account.

The amount of assistance payable to an operator is computed under the current formula whereby only gold mines with an average production cost of $26.50 or more are eligible for assistance. When calculated on the basis of all eligible ounces produced, the maximum assistance payable amounts to $10.27 per ounce.

There were 39 lode gold mines and 18 placer gold mines in receipt of assistance during 1967. Four gold mines had average costs of production less than $26.50 an ounce.

Lode gold mines usually apply for assistance payments on a quarterly basis, while a single annual payment is generally made to operators of placer gold mines. In 1967, 180 separate applications were examined by the Audit Services Branch, approved by this Department and transmitted to the Chief Treasury Officer for payment.

The amounts paid to gold-mine operators to March 31, 1968, for the years 1948 to 1967 inclusive totalled $246,360,675.18 on a production of 55,369,122 fine ounces of gold produced and sold in accordance with the requirements of the Act.

The amount of assistance paid with respect to each calendar year since the Act was introduced is as follows:

1948 –	$10,546,315.84	or 3.33 per ounce produced
1949 –	12,571,456.90	or 3.48 per ounce produced
1950 –	8,993,490.51	or 2.55 per ounce produced
1951 –	10,728,503.71	or 3.30 per ounce produced
1952 –	10,845,978.62	or 3.75 per ounce produced
1953 –	14,680,110.42	or 4.62 per ounce produced
1954 –	16,259,179.23	or 4.29 per ounce produced
1955 –	8,885,478.73	or 2.97 per ounce produced
1956 –	8,667,235.38	or 3.46 per ounce produced
1957 –	9,679,753.32	or 3.55 per ounce produced
1958 –	11,420,463.70	or 4.29 per ounce produced
1959 –	12,001,753.43	or 4.91 per ounce produced
1960 –	12,362,517.59	or 5.02 per ounce produced
1961 –	12,666,658.77	or 5.30 per ounce produced
1962 –	14,355,013.49	or 6.16 per ounce produced
1963 –	14,319,757.65	or 5.51 per ounce produced
1964 –	15,419,600.95	or 5.83 per ounce produced
1965 –	15,309,941.32	or 6.30 per ounce produced
1966 –	14,620,449.55	or 6.86 per ounce produced
1967 –	12,027,016.07	not available

Explosives Division

Since its inception in 1920, the Explosives Division has been responsible for the administration of the Explosives Act, a statute enacted in the interest of public safety to control the manufacture, authorization, storage, sale, importation and transportation by road of explosives.

All licences, permits and certificates for manufacture, storage, transportation by road and importation are issued from the Division's main office in Ottawa. The following were issued in 1966-67 and 1967-68.

	1967-68	*1966-67*
Factory Licences	42	34
Magazine Licences (storage for sale)	410	383
Temporary Magazine Licences (storage for private use)	1,290	1,219
Registered Premises (storage of small quantities for sale)	76	79
Explosives Transportation Permits	314	404
Explosives Importation Permits	643	642
Ammonium-Nitrate and Fuel-Oil (ANFO) Permissions	23	19

Inspectors of the Division inspect all storage facilities and vehicles used for the transportation of explosives. In addition factories are checked regularly, and proposed sites examined for approval. Accidents involving explosives are investigated and reports submitted. New explosives and equipment are evaluated and assistance is given to federal and provincial government agencies, explosives manufacturers, construction and transportation agencies in matters concerning explosives.

The following inspections were carried out during the year:

Factories	52
Storage magazines	2,294
Transportation vehicles	238
Fireworks and ANFO	65
Unlicensed premises	210

There were two amendments to the Explosives Regulations during the year. One restricted the size of firecrackers that may be imported into Canada to 11/2 by 1/4 inches, thus incorporating into the Regulations a Directive Letter from the Minister that was issued in 1962 and has been in effect since that time. The other permitted transportation of explosives in quantities greater than 10,000 pounds over approved "isolated" highways. This was introduced to assist industry in reducing costs of explosives for use in the construction and mining developments in remote areas.

The number of "on-site" manufacturing installations for explosives of the blasting-agent type increased considerably, and there is every indication that this trend will continue.

Production of explosives in licensed factories remained approximately the same as last year – just under 300 million pounds, plus an estimated quantity of on-site mixed ANFO of 50 million pounds.

The Division continued a safety campaign by distributing literature to licencees, provincial boards, safety organizations and to the general public on request. Over 20,000 pamphlets were distributed during the year and a revised sales-record form was adopted for use by explosives distributors and dealers.

The 1967-68 period was marred by two fatal accidents, both in the manufacture of fireworks.

In the first accident it is believed that an explosion occurred while the operator was adding composition to the hopper of a machine pelleting fireworks stars. As a result of this accident, the company was advised that future operations of this nature may only be performed where the operator has the protection of a remote-control process.

In the second accident, a supervisor and an operator were starting up a new quick-match process when the supervisor saw a flash. He alerted the operator who escaped without difficulty, but for some reason the supervisor was delayed and failed to escape from the burning building.

There were 46 prosecutions for violations of the Explosives Act and Regulations; approximately half of these were violations of the regulations governing the transportation of explosives by road.

The Division maintains offices at three locations – Ottawa, Halifax and Vancouver.

A separate report giving more details is published by the Division.

WATER GROUP

Marine Sciences Branch

The Marine Sciences Branch of the Department of Energy, Mines and Resources carries out federal research and surveys to assure safe navigation and to support development of natural resources in Canada's inshore and coastal waters.

The Branch is organized along regional lines with offices in Dartmouth, Nova Scotia, in Victoria, British Columbia, and in Ottawa. The headquarters is situated in the Department of Energy, Mines and Resources complex in Ottawa.

The Branch is responsible for the production and distribution of all Canadian navigational charts and tidal information. Its surveys of geological and geophysical characteristics of the ocean floor provide basic information for mineral exploration. Its studies of oceanographic phenomena are directed to support fisheries, transportation, coastal engineering and defence.

In 1967 the Branch fleet totalled twelve ships supported by 75 sounding launches and 95 smaller craft.

The modernization of the fleet continued with the commissioning of three new vessels, the *Parizeau, Vector* and *Dawson,* for continental-shelf studies. They have replaced the *Ehkoli, Parry* and *Cartier* which were retired from service. In addition, three charter vessels were employed during the year to meet the continued high demands for oceanic research and to support pollution studies in the Great Lakes.

Continued emphasis has been placed on the design and construction of specialized vehicles for research. The first of these vessels, the CSS *Limnos,* built for pollution investigations, will be in service in 1968 on the Great Lakes. Designs and modelling of a catamaran-type vessel are well under way in expectation of adding another special research vessel to the Great Lakes operations.

Design studies have also been completed for a fast (25 knot) 80-foot cutter for the Great Lakes for high-speed synoptic surveys. This craft will be powered with gas-turbine engines and will be specially fitted out with laboratories and all-weather capabilities.

Plans for expansion of facilities at the Bedford Institute are progressing, and it is expected that the end of 1968 will see the completion of the extension of the laboratory wing to provide a 50-per-cent increase in lab accommodation and the provision of a breakwater and floats for mooring of smaller craft.

Although the overall work of the Branch is designed to insure coordination and integration of the efforts of its two specialties of hydrography and oceanography, it is instructive to report its accomplishments under these two main headings.

HYDROGRAPHY

In 1967, the Canadian Hydrographic Service began a systematic program of field revisory surveys directed at the maintenance of the 900 Canadian navigation charts. During the year, 59 charts were revised, and material is now being prepared for an extensive revision program for 1968 in both the Central and Atlantic Regions.

The demand for charts by Canadian and American pleasure-craft operators cruising to Expo '67 raised the 1967 chart distribution totals to an all-time high of 285,000 charts.

During the year, the Canadian Hydrographic Service published 193 navigation charts. This total included 27 new charts, 52 new editions, 57 corrected reprints, 15 reprints, 2 supplementary prints and 30 special charts. In addition, 54 *Catalogue Index* pages, 9

Information Bulletins and 7 *Pilot Index* maps were published. New editions of the *Great Lakes Pilot,* Volume 1, and the *Pilot of Arctic Canada,* Volume 3, were published. Eight *Supplements* to existing *Pilot* editions also were issued.

It is interesting to note that for the first time meters were used to portray soundings and depth contours in Canadian charts: two bathymetric charts of the Arctic ocean, two charts of the continental shelf off Nova Scotia and southern Newfoundland, and four charts of the waters off the Labrador Coast. The latter are being derived from charts compiled by the Federal Republic of Germany.

The Canadian Hydrographic Service is putting substantial effort into the application of automated techniques in hydrographic surveying and chart production. The work is being carried out by work groups in Ottawa, Saskatoon, Dartmouth, and a work group in Victoria will join the project in 1968. At the same time increased effort is being made in the training of new hydrographic survey staff. A record class of 23 began instruction in Ottawa this year.

Pacific Region. The hydrographic surveys in the Pacific Region ranged along the entire coast and into the Western Arctic during 1967, with the work being done by the field parties on the *Wm. J. Stewart, Marabell* and *Richardson.* Tidal, current and scientific investigations were carried out from the *Parry* and *Parizeau.* The *Ehkoli* was also operated in support of scientific studies.

CSS *Wm. J. Stewart* completed the survey of the approaches to Burrard Inlet and made a reconnaissance for Mini-Fix station sites in the Strait of Georgia for 1968 surveys. The control for the re-survey of Prince Rupert Harbour was completed and the general charting program in the Chatham Sound area, using both conventional and Mini-Fix survey equipment, was continued.

CSS *Marabell* completed surveys of the approaches to Nanaimo Harbour, the popular small-craft harbour of Prideaux Haven and the harbour and dock area of Gold River on Muchalat Inlet. A survey of Portland Inlet and approaches and a survey of Meyers Passage for the Royal Canadian Navy was also completed. In addition, surveys of Seymour and Belize Inlets and of Departure Bay north of Nanaimo were started.

After spending the winter in Victoria undergoing her quadrennial refit, CSS *Richardson* revised 25 charts around Vancouver Island before returning to the Western Arctic. While rounding Cape Barrow, she was trapped in the Arctic pack ice until freed by USCGS *Northwind* and CCGS *Camsell.*

Central Region. The most significant activities of the Region were concentrated in obtaining field information for the production of nautical charts. A major hydrographic survey using advanced survey techniques was completed in the Arctic Archipelago and support was provided to field activities in Great Lakes research conducted from the Canada Centre for Inland Waters at Burlington, Ontario. Important developments in semi-automated methods of processing field data were field tested.

Because the majority of field operations within the Region are conducted by shore-based surveys, the emphasis on mobility and flexibility was continued. Throughout the survey season hydrographic operations were supported by one helicopter which moved between the various field parties as required.

Small-boat charting along the Trent-Severn Waterway, commenced in 1965, was continued. In an endeavour to expedite the charting of this significant small-craft route, two parties were assigned to the project and successfully completed the sections Bobcaygeon to Stoney Lake and Bay of Quinte, Murray Canal.

An excellent start was made on the systematic survey of Lake of the Woods, required for the production of a new series of charts which will be of considerable importance to all users of the lake, and particularly to the pleasure-boat operators. Data were obtained for the production of the first chart depicting Kenora and approaches.

In the entrance to Georgian Bay a major survey was completed using electronic position-fixing equipment and high-speed sounding launches. A sub-unit of this establishment commenced a detailed survey of the main pleasure-boat routes between Port Severn and Parry Sound on the eastern side of Georgian Bay.

A new survey party was established and commenced charting of the complex Upper Ottawa River. It is anticipated that new charts in this area will not only encourage tourism but will also expedite engineering studies. Field surveys were completed from Chats Falls to Bryson during the 1967 season.

Studies directed towards the automation of field-data processing were continued. Sounding records can now be successfully digitized in the office using semi-automatic techniques and field data plotted centrally using departmental computer facilities.

Atlantic Region. The hydrographic survey of the Grand Banks was continued during 1967, with geophysical coverage throughout the survey. Decca Lambda was used to position the ship, as in previous years, but during much of the survey, the *Kapuskasing* surveyed along parallel lines to the *Baffin,* in an evaluation of the potential of multi-ship survey operations. Considerable interest has already been expressed by commercial organizations in the results from the survey.

Off Newfoundland's northeast coast, CSS *Acadia* continued the survey of Sir Charles Hamilton Sound after surveying Petit-de-Grat Harbour on Cape Breton Island, the site of a large fish-processing plant.

A team of hydrographers sailed to the Eastern Arctic on CCGS *Sir John A. Macdonald,* transferring later to CCGS *d'Iberville.* A survey of the entrance to Resolute Bay was completed and an extensive reconnaissance of the fiords on the northeast coast of Baffin Island was undertaken.

The magnitude of the surveying task which still lies ahead has been realized for many years. The hydrographic-development group established to devise and implement methods for improving the speed and accuracy of surveys was very active during the year in obtaining and evaluating equipment to be used in the automation of many facets of hydrography. Electronic-positioning equipment was tested aboard CSS *Baffin* and CSS *Hudson* during the summer, and the work on semi-automatic chart scalers progressed favourably. The Gerber Plotting Table was made operational and a series of programs was devised for its operation. Orders were placed for two satellite navigation receivers to be delivered during 1968, and evaluation will be made during a cruise of investigations of the Mid-Atlantic Ridge.

OCEANOGRAPHY

Under this broad classification is included the wide range of marine investigations which primarily are not intended to insure safety of navigation. These include geophysical and geological investigations of the deep structure of the continental shelves and of the floors of the open ocean. The importance of these studies is being emphasized by a growing interest in the potential mineral resources of the extensive shelves under Canadian jurisdiction, and by increasing international concern over the control and disposition of mineral resources on the deep ocean floor.

Oceanographic research in the Branch includes comprehensive studies on waves of all periods from short wind waves to those of astronomical tides and longer. These studies involve theoretical, observational and experimental approaches, and findings will apply to harbour and break-water design, to navigation, and to tidal-power problems, among others. There are also basic studies on the mechanics of air-sea interaction, a better understanding of which will apply not only to wave prediction, but to improve weather forecasting.

Studies in oceanic and coastal circulation are carried out to better understand the means of transport of water properties and the dynamics of mixing processes in the oceans. They have particular application to fisheries, to defence, and to the assessment and prediction of pollution, both locally and over large areas. The increasing possibility of large-scale oil pollution has demanded accelerated studies of such aspects as the distribution of naturally occurring chemical elements in the sea and those radioactive elements recently introduced.

The Branch publishes the results of its oceanographic research in scientific journals and is developing a series of charts to display its information on bottom characteristics. The following paragraphs should serve to illustrate the variety of activities and accomplishments over the past year.

The Branch provides a centralized data centre for oceanography in Canada through the facilities of the Canadian Oceanographic Data Centre in Ottawa. It is supported by environmental and systems specialists engaged on climatological analyses and retrieval of data to meet the needs of industry and research in Canada and abroad. The Centre has steadily increased the scope of its holdings and the sophistication of its processing system over the past year.

Theoretical hydrodynamical and tidal studies continue to be a major activity in Ottawa, with application to areas of particular Canadian interest and development, namely the Bay of Fundy, St. Lawrence River and Gulf.

The two regional centres which undertake oceanographic research are those on the Pacific and Atlantic coasts. In the development of an eventually well-rounded program, attention has been focussed first on building up an adequate activity on the Atlantic coast. Up to the present the extension of the activities of the Branch on the Pacific Coast has been limited.

Pacific Region. The Branch has undertaken an investigation of the tides and currents in the Strait of Georgia as a part of a cooperative program with the Fisheries Research Board. This investigation is intended to meet the needs of fisheries, navigation and harbour developments, and pollution abatement.

Support is being provided to the Ocean Weathership program. This investigation of the fluctuations in oceanic properties at Ocean Station "Papa" off the west coast represents the longest and most detailed continued study of ocean time variation anywhere in the world, and is of wide international interest.

Atlantic Region. Basic research at the Atlantic Oceanographic Laboratory, Bedford Institute, has now been firmly established on a sound and generally comprehensive range of activities. The year saw some expansion in research which provides more immediate and practical returns, such as the study of swell in Halifax Harbour for the National Harbours Board. It is expected that future growth will emphasize applied investigations.

Variability in the ocean is being investigated with growing vigour; one result of such studies will be a firmer appreciation of the reliance which can be placed on synoptic

oceanographic measurements. The collection of time series of observations, which form the basic data for studies in variability, cannot be made economically in the traditional manner using research ships. Moored buoys with recording oceanographic instruments are likely to be extensively used in such research, and also in research with short-term applied objectives. A project using such techniques has been in progress throughout the year, and a great deal has been learned of the value of such methods, as well as of the inherent problems and difficulties associated with them.

The comprehensive coverage of the North Atlantic in high latitudes in the winter which was undertaken in the past two years by the cruises to the Labrador Sea and Irminger Sea has produced a unique collection of data. Although not yet completely worked up, it promises to throw a significant new light on the formation of deep water and on the deep circulation in the whole of the North Atlantic Ocean.

In marine geophysics, the major effort this year was devoted to continuation of the gravity and magnetic survey of the Grand Banks and off shelf to Flemish Cap, working jointly with the hydrographers in their recharting of the Banks; within an area of 33,100 square miles, 16,500 line miles of geophysical data were obtained, a significant contribution. The marine geologists carried out their main field work along the Scotian Shelf, Grand Banks, Labrador Shelf and the associated continental slopes.

The close and satisfying working relationships between the Bedford Institute and other marine research organizations continued to develop during the past year. CSS *Hudson's* cruise to Expo '67, where she was on display for a week demonstrating the methods and potential of oceanography to some 20,000 visitors, was undertaken jointly with Dalhousie Institute of Oceanography; a subsequent *Hudson* cruise was also operated jointly between the Bedford Institute and Dalhousie, whilst visiting scientists were accommodated on many other cruises during the year.

Policy and Planning Branch

The Policy and Planning Branch's functions include advice on national and regional policies for water and related resources; co-ordination of federal and federal-provincial government policies and activities; basic and applied research, mainly on the socio-economic, institutional and jurisdictional aspects of resources; comprehensive basin and regional planning; and administration of certain acts and regulations.

The Branch consists of three divisions and an administration. The newest of the Department's branches, it is still developing and hiring staff. During 1967-68 it undertook a number of studies and projects and made plans to initiate several more as soon as personnel and other resources permit.

The Branch library, attached to the administration, integrated the entire collection of the former Geographical Branch library with that of the Policy and Planning Branch and other collections of the Inland Waters Branch. It thus acquired one of the major collections in Canada on geography and water resources. It also examined and discussed in seminars the development of automated systems for the collection, storage, dissemination and retrieval of non-numerical information.

POLICY ADVISORY, CO-ORDINATION AND ADMINISTRATIVE DIVISION

This Division conducts and co-ordinates studies leading to recommendations on water management and development by federal and federal-provincial agencies. It also negotiates and administers federal-provincial agreements for research, planning and development of water resources as well as annual grants in aid of water-resource research in Canadian universities.

During 1967-68 the Division reviewed federal water policies and programs. It helped prepare new legislation covering federal and federal-provincial activities in the water-resource field. There were many consultations with federal and provincial officials.

Particular attention was given to water pollution. On the basis of the guidelines announced by the Pollution and Our Environment Conference as well as other studies, the Branch developed several proposals for federal and federal-provincial measures to combat pollution. These included research, better intergovernmental co-ordination, the creation of a task force on water quality, comprehensive basin and regional planning, pilot projects, financial assistance for pollution control, and measures to improve training and education of water-resource personnel. After approval by the federal government, the proposals were submitted to the provinces.

Co-ordination within the federal government is in the hands of the newly established Interdepartmental Committee on Water Programs and its sub-groups. The committee replaced the Advisory Committee on Water-Use Policy, created in 1955. Division personnel serve as research workers, secretaries and in other capacities.

The Division maintains liaison between federal agencies and the Canadian Council of Resource Ministers. The latter is composed of eleven ministers – one from each province and one from the federal government. The Minister of Energy, Mines and Resources was president of the council during 1967-68. The council is advised and assisted by a co-ordination committee, headed by an official of the Department. Interdepartmental liaison to ensure a unified federal approach to the work of the council is provided through the Interdepartmental Committee on Resources, which deals with all natural resources. Among the many projects undertaken for the council were the preparation of reports and the arrangement of a workshop seminar on water resources. The seminar, scheduled for the fall of 1968, will provide the ministers and their aides with an opportunity for studying and discussing basic issues in water policy and planning.

In response to the need for more trained personnel in water resources, a National Advisory Committee on Water Resources Research was established in 1967. It consists of experts from both federal and provincial agencies, universities, and private industry. The committee has two sub-committees, one on social science and one on natural science. Chaired by an official of the Department, the committee has three functions: to advise the Minister on needs and priorities for water-resources research in Canada; to help co-ordinate such research; and to review and make recommendations on applications for grants in aid of water research dispensed by the government. In 1967-68, these grants amounted to $192,167. The committee's secretariat is provided by the Branch.

PLANNING DIVISION

This Division undertakes and co-ordinates water-resource studies either on its own or in co-operation with other agencies. Such studies include the economic, legal, social and financial aspects of regional and national water policies and projects.

Divisional staff continued to provide technical advice and assistance for the water studies undertaken by the Atlantic Development Board. These studies are being directed by a supervisory committee made up of officials from several federal agencies and the four Atlantic provinces. The head of the Branch's Atlantic Regional Unit is the secretary of the committee.

In the central region, the Branch participates in such agencies as the Co-ordinating Committee on Northern Ontario Water Resource Studies. Another joint committee with Ontario is trying to develop standards for common water-resources planning and development.

In the Prairies, Branch officials took part in the negotiations on the Saskatchewan-Nelson Basin Study, which was initiated in 1967. Discussions were also held with officials of Manitoba, Saskatchewan, and Alberta on other subjects. A joint committee was established with Alberta to design and undertake economic studies of water resources in the South Saskatchewan Basin.

In the Pacific region, the Branch helped to negotiate the Fraser River Agreement, concluded in 1968. In December 1967 the Branch, through the University of Victoria, financed a two-day seminar in Vancouver on the methodology of forecasting water demand. Participants came from public and private agencies.

RESOURCES RESEARCH CENTRE

The Resources Research Centre carries out basic research on the best use of national resources through integration of existing knowledge in the economic, sociological and technological fields. It also advises other divisions and branches and administers grants in aid of geographical research in Canadian universities. The staff of the Centre was increased in November 1967 by the transfer of the Economic Geography Division from the former Geographical Branch. Much of the effort during the year was concentrated on planning and staff organization.

Several studies were started on environmental problems, notably the implications of the guidelines proclaimed by the Pollution and our Environment Conference. The Branch represents the Department on the Alberta Advisory Committee on Pollution Control. This committee, which advises provincial authorities on the control of air, soil, and water pollution, illustrates the kind of consultation and communication recommended by the aforementioned conference.

Research into the application of air photographs to watershed planning is continuing. Attention is directed especially to determining what areas may be susceptible to flooding. A paper prepared on this subject aroused wide interest.

A survey and analysis of urban structure in the Atlantic provinces was conducted for the Atlantic Development Board. The study evaluates various aspects of urban potential such as type of establishment, employment structure, socio-economic characteristics, business methods and attitudes, population movements and consumer patterns. The results have been published. Another study in progress examines the socio-economic factors in the problems of regional development in Newfoundland.

Field work for the regional economic studies of the Prairie provinces was undertaken with the co-operation of other government departments and outside agencies. Particular emphasis was placed on transportation. The project was later transferred to the Economics Branch of the Department of Agriculture.

Inland Waters Branch

The Inland Waters Branch was created on April 1, 1967, to carry out primary continuing federal research and investigation into the inland water resources of Canada. Its creation, which resulted from the integration of the Water Research and Water Resources Branches, was prompted by the need for co-ordinating all inland water survey and research work within one branch.

From the Water Research Branch came the Great Lakes and Water Quality Divisions, which retained their names in the changeover, and the Hydrology Division which formed the nucleus for the new and larger Hydrologic Sciences Division. From the Water Resources Branch came the Canadian Hydrometric Survey which was renamed the Water Survey of Canada, and the Planning, Great Lakes and Research Divisions which combined to form the New Engineering Division. The Tides and Water Levels Section which had formed part of the Water Research Branch was attached to the Water Survey of Canada in 1967; however, responsibility for this section will revert to the Marine Sciences Branch at the close of the current fiscal year.

The Branch is responsible for the provision of all possible technical information concerning inland water resources; the conduct of research into the behaviour of water as a material; the comprehensive examination of existing pollution conditions in lakes, rivers and streams, with particular reference to the causes of, effects of and possible abatement measures for such pollution; the engineering investigation of river systems or portions thereof; participation in the planning and negotiations involved in water development and program appraisal being conducted by groups representing several agencies – federal, provincial, United States or other; co-ordination of these varied approaches to the understanding and solution of water problems, encouragement and support of research and investigatory activities in the freshwater field undertaken by universities or other appropriate agencies.

This work provides the Government of Canada with information essential to the development and application of an effective national water policy. The preservation and renewal in perpetuity of water resources are essential to a nation's well-being, and indeed are basic to its survival.

Subsequent sections outline briefly the activities of the Inland Waters Branch. A significant effort was made in establishing the Canada Centre for Inland Waters, located on the shores of Lake Ontario at Burlington. It will eventually become a major interdisciplinary water-studies centre large enough to allow biologists, engineers, chemists physicists, geologists, economists, sociologists and other specialists to work together on water problems.

A start on the Centre was made in 1967 with the establishment of a 25,000-square-foot trailer complex comprising offices and research facilities. The Department of Energy, Mines and Resources has the major function of co-ordinating the Centre in collaboration with the Fisheries Research Board and the Department of National Health and Welfare. University professors and students will carry out research at the Centre to bring the academic research view to bear on these important problems and to help train water specialists. Industry will be involved in co-operative research projects and in undertaking, by contract, portions of the overall research. An advisory committee consisting of representatives from government agencies, industry and universities will participate in the planning of the work carried out at the Centre.

WATER SURVEY OF CANADA

The Water Survey of Canada conducts a systematic survey of streamflow, water levels and water-borne sediment throughout Canada. In addition it carries out snow and glacier surveys and water-power surveys, the latter mainly in areas of federal jurisdiction. On rivers subject to dangerous floods, frequent observations of stage are obtained and a flood-warning service is provided during danger periods; on many rivers, a study of river conditions in the upper reaches together with current meteorological data makes possible day-by-day computation of probable flood stages in the lower reaches. Although these activities are designed to meet the requirements of the federal government, an increasing portion of the total effect is aimed at satisfying requests from the provinces.

The Water Survey of Canada and its predecessors have collected and published basic streamflow and water-level data on a national basis for more than half a century; the sediment survey has been in operation since 1961. These surveys are being expanded steadily and at present are conducted from 27 field offices extending from St. John's, Newfoundland, to Whitehorse, Yukon Territory.

With such widespread operations the Water Survey has been assigned the additional task of expanding its survey network to include the collection of data on water quality, groundwater, snow, ice and tides.

During the year under review, some 250 stations were added to the gauging network, bringing to approximately 2,200 the total number of streamflow and water-level stations. Sediment data are gathered at 77 of these stations, an increase of 22 stations during the year.

An intensive program of sediment surveys on the lower Fraser River was continued to provide a sound basis for the maintenance and improvement of the navigation channels in that river. A similar program is under way on the South Saskatchewan River to determine the effect of sediment deposition behind the Gardiner Dam and the amount of erosion downstream of the dam caused by the release of water which, being relatively sediment-free, will have an affinity for sediment.

Approximately 35,000 station-years of record, representing all historical streamflow data to 1966, were key-punched and converted to magnetic tape for rapid retrieval. These data will be available as print-outs or on magnetic tape for computer processing early in 1969. Also, special equipment has been obtained and the development of a system for the automation of streamflow computations should be realized in 1969.

Engineers of the Water Survey of Canada are members of, or participate in the activities of some 20 engineering boards, committees and special studies in connection with various aspects of national, international and inter-provincial water problems. These responsibilities include major streamflow-measurement programs in the interconnecting channels of the Great Lakes, and on the St. Lawrence and Nelson rivers.

Tides and Water Levels. The objectives of the Tides and Water Levels Section are to supply the maritime, engineering and scientific communities and the general public with authoritative information and up-to-date accurate data and to provide vertical control for all hydrographic surveys. To fulfill this function, the Section maintains a continuous record of tides and water levels in Canada's coastal waters and the navigable waterways of the St. Lawrence River and Great Lakes system. From these records, water- and tide-level tabulations are prepared and distributed on a weekly, monthly and annual basis. In addition, tidal predictions are prepared and published annually for the use of Canadian seafarers.

To keep abreast of the increasing demand for data, many improvements to recording and data-acquisition systems were made, especially in the Arctic, sub-Arctic and off-shore areas. Several meetings with the United States Environmental Science Services Administration, United States Lake Survey, Department of Transport, National Research Council and others were held during the year to discuss common problems.

Permanent-gauge construction along the West Coast and the Western Arctic was deferred because of tidal and current surveys requested for the Straits of Georgia and Juan de Fuca. In the Great Lakes-St. Lawrence River system, and along the Atlantic Coast and Eastern Arctic, extension of gauging facilities was successfully completed. A major tidal-measurement program on the St. Lawrence River was completed on schedule and the data are being analyzed.

The network of automatic announcing and telemetry gauges was expanded, and it is now possible to obtain instantaneous water-level information at specific locations between Lake Superior and Trois-Rivières.

Considerable work was carried out for the Atlantic Tidal Power Programming Board and the co-operative effort with the Scripps Institute of Oceanography in preparing long-term hourly time series of mean sea-level data for Victoria, British Columbia, and Saint John, New Brunswick, was completed.

HYDROLOGIC SCIENCES DIVISION

The objectives of the Hydrologic Sciences Division are:

1. To develop new concepts in the evaluation of Canada's water resources, leading to improved methods of management and utilization.
2. To take part in international water-balance studies such as the International Hydrological Decade and the International Field Year on the Great Lakes.
3. To enter into joint research with universities, provincial authorities and other government departments and agencies in order to increase the understanding of the basic processes that govern each phase of the hydrologic cycle; particular emphasis is placed on relating new knowledge to Canadian situations and applications.

The Hydrologic Sciences Division has been divided into four operational Subdivisions – Glaciology, Groundwater, Hydrophysics and Water Science. Hydrophysics was in its formative stage in 1967; Water Science was being staffed during the year.

In addition to the four subdivisions, the Division provides administrative services to the Secretariat, Canadian National Committee, and International Hydrological Decade.

Glaciology. Glaciological research is conducted in the field and in the laboratory. Field investigations include studies of the mass, water and energy balance on selected glaciers as a means of gaining a greater understanding of the role of snow and ice in the hydrologic cycle. Investigations emphasize the relationship between climate and glacier variations and are aimed at ways of predicting glacier variations and meltwater yields. Glacier basins studied include the chain of five glaciers across the Cordillera in southern Alberta and British Columbia, and the Decade Glacier on Baffin Island. Similar studies were also initiated on the Berendon Glacier in northern British Columbia in order to fill a large gap in the north-south chain of glaciers along the west coast of the Americas. Movement studies were made on all glaciers and detailed studies of the application of terrestrial photogrammetry to glacier mass-balance studies were made on temperate and cold glaciers.

Personnel worked for short periods with the Defence Research Board on glacier surveys on the Per Ardua and the Gilman glaciers on Ellesmere Island and with the

Icefield Ranges Research Project on measurements of the meltwater from the "Fox" Glacier, Yukon.

An inventory of the perennial snow and ice in Canada is one of the major projects being undertaken for the International Hydrological Decade. Two pilot studies were completed, one in the Cordillera and one in Arctic Canada as the first step in this inventory. Both studies formed integral parts of the inventory manual which will be used by all countries participating in the Decade program.

Final compilation of the remaining six maps showing distribution of glaciers in Canada was completed. The Division worked with the Surveys and Mapping Branch on the compilation of detailed topographic maps depicting four of the International Hydrological Decade glacier basins and on the preparation of similar maps for the Steele Glacier.

Groundwater. The last few years have seen a marked increase in the demand in Canada for information on groundwater. Not only is there a need for a reasonably accurate estimate of the magnitude of this resource, but also a need for vastly expanded research to increase our knowledge of the behaviour of groundwater.

Until recently, most research in Canada was basic, aimed at a greater understanding of the deep groundwater flow at depths of 100 to 1,000 feet. However, a greater effort is being directed towards expanding the facilities for pure and applied research. Instruments have been designed which more accurately measure rainfall, evaporation from the ground, infiltration of water into the ground and the natural flow of groundwater.

During 1967, experimental plots for groundwater hydrology were established in all parts of Canada and the immediate results are proving invaluable. They have revealed the pattern of groundwater flows in the prairie regions; they have shown that sloughs form a useful function in a groundwater system; they have shown where to look for drinking water, why lakes are saline or fresh and how much seepage occurs under dams. In Ontario, greater insight has been gained into the flow of groundwater into lakes and rivers. Flood forecasting in British Columbia has been improved, research on saltwater intrusions into freshwater locations in coastal areas of Prince Edward Island and New Brunswick has been advanced, and mine pollution of rivers in New Brunswick evaluated. Studies of miscroscopic animal remains in prairie sloughs aim at establishing whether sloughs are permanent or temporary – knowledge that will be of immense value in better management of prairie wetland.

Hydrophysics. Winter studies of the water balance of a typical Arctic basin, frozen-ground resistivity and frost heave in mud boils have been undertaken in the Mackenzie Delta, Northwest Territories.

Discharge, snow pack, ice thickness and lake temperature have been measured in the Boot Creek Basin, south of Inuvik, and are being compared with similar measurements obtained at Gaynor's Lake, south of the Boot Creek Watershed.

Co-operative projects with the University of British Columbia are under way to determine the heat budget of a typical Delta lake and the cryostatic pressures in mud boils during freeze-back. Problems encountered in making the measurements have pointed up the requirement for development of instrumentation suitable for use during Arctic field observations.

Members of this Division contribute to the development of remote-sensing techniques, with special reference to evaluation of national water resources. Other

participants are the Geological Survey of Canada, the National Research Council and the Defence Research Board. An infrared scanner, purchased during the year, is now undergoing modification to provide improved imagery.

International Hydrological Decade. The secretariat's duties are guided by the 26-member Canadian National Committee, which co-ordinates the country-wide scientific investigation and assessment of water resources under the 1965-74 schedule for the International Hydrological Decade.

The committee includes executive personnel from federal and provincial water-resource agencies and scientists from seven Canadian universities. The chairman of the committee represents Canada internationally during the country's second 2-year term on the International Co-ordinating Council. Day-to-day administration of the national program is carried out by the Secretariat, which has been established within the Inland Waters Branch.

Ninety-seven countries and some 20 international organizations from around the world are engaged in the Decade program. The Canadian share consists of 185 research projects on all aspects of the hydrologic cycle, including detailed investigation of 45 watersheds, 34 of which are representative basins, and 11 experimental. In addition, another 14 basins are being considered for 'benchmark' studies.

GREAT LAKES DIVISION

The Division was organized during 1966 to carry out comprehensive research on the physical, chemical and geological processes acting in or affecting the Great Lakes, especially water circulation, composition and temperature, the distribution and assimilation of pollutants, the processes at the air-water interface and the relationship between the water and the shore and bottom materials.

Such knowledge will greatly increase the Department's ability to provide data and advice in support of the International Joint Commission reference on pollution in the lower Great Lakes, as well as to the Ontario agencies concerned with pollution abatement, to industries and others.

The year 1967 saw the firm establishment of the Great Lakes Division and a major start made on the development of the Canada Centre for Inland Waters (C.C.I.W.) at Burlington, Ontario. By the end of the year, the Centre was housed in a 25,000-square-foot trailer complex, and was staffed by the Great Lakes Division and units of the Water Quality Division and the Fisheries Research Board.

On December 9, the launching of C.S.S. *Limnos,* the first major research vessel for the Canada Centre, took place at the Port Weller shipyards. This 147-foot 650-ton vessel began scientific service early in 1968.

Much of the Division's time was taken up with the technical reports for Lakes Ontario and Erie required by the International Joint Commission pollution reference. However, some important elements of a longer-range program were developed.

Two major vessels were chartered and operated by Marine Sciences Branch on behalf of the Great Lakes Division in 1967. The two ships were the M.V. *Theron,* a 199-foot 850-ton vessel which operated mainly in Lake Ontario, and the M.V. *Brandal,* a 137-foot 350-ton vessel which worked mainly in Lake Erie.

Chemical Limnology. The Great Lakes and the Water Quality Divisions of the Inland Waters Branch collaborated with Department of National Health and Welfare in 21 cruises

on Lake Ontario, and 15 cruises on Lake Erie. A total of 285 samples from both lakes were analyzed by the Water Quality Division for some 30 different properties. An additional 1,000 samples from Lake Erie were analyzed on board ship for eleven properties. Department of National Health and Welfare personnel also undertook bacteriological analyses of samples from the two lakes.

A continuing series of monitoring cruises is planned to assess the change with time of the concentrations of inorganic solutes in the Great Lakes. These cruises will become less frequent as our knowledge increases.

Physical Limnology. The purpose of physical limnology is to discover the basic physical characteristics of the Great Lakes waters and to seek out and explain the distribution and variation of physical properties. For example, a number of moorings with current meters and other instrumentation have been established to provide information on the general circulation patterns and temperatures within the open lakes. Periodic flights over western Lake Ontario to undertake measurements with a thermal scanner, and airborne radiation thermometer, aerial cameras and radiometers are scheduled for surveys of lake surface phenomena and radiation balance; co-ordinated with the airborne survey is a motor launch equipped with an irradiance meter and equipment for measuring temperature profiles. Analysis of water-level data from three gauging stations was initiated to study the free surface modes and determine the periods of oscillation in western Lake Ontario.

Limnogeology. In 1967, chemical studies were undertaken to identify the organic materials present in the bottom sediments of Lakes Ontario and Erie. A geological study to differentiate and classify offshore sediments and to determine their sedimentary sequence in the post-glacial sediment column is also under way. This study is to determine present areas and rates of subaqueous erosion and accumulation, and the effect of crustal movement upon water levels and basin sedimentation during the past 10,000 years. A similar program is under way in the nearshore zone (0 - 10 fathoms).

ENGINEERING DIVISION

The Division serves as the engineering arm of the Departments's Water Group. It provides technical advice on water-resources development and control and carries out hydrologic, hydraulic and water-resources investigations.

Members of the Division participate in some 30 international, federal-provincial or inter-departmental engineering boards and committees. For example, a special staff in Vancouver provides technical support to the Canadian officers of the Columbia River Treaty Permanent Engineering Board and assists in the administering of conservation projects in British Columbia by assessing and reviewing contracts for new projects and inspecting the progress of existing projects. The Division also provides technical advice to the Department of External Affairs in connection with an international tribunal's investigation of the causes of high water on Lake Ontario in 1952.

Great Lakes. The Division provides engineering advice on the regulation and control of the waters of the Great Lakes-St. Lawrence Basin. Because of the international nature of this important drainage system, the Division is called upon to provide technical advice to and carry out investigations for the International Joint Commission, often working in close co-operation with counterparts in the United States.

From an office in Cornwall, members of the Division oversee the regulation of Lake Ontario and the St. Lawrence River. They also participated in a continuing study of the feasibility of further regulation of the Great Lakes, a major undertaking under the aegis of the International Joint Commission. Studies also were undertaken on behalf of other international boards with responsibilities in the Great Lakes-St. Lawrence Basin, including the St. Lawrence River Board of Control, Lake Superior Board of Control, Niagara Board of Control and the Co-ordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data.

An important contribution is being made on behalf of the American Falls International Board, appointed by the International Joint Commission to investigate and recommend what measures would be feasible and desirable to remove the rock debris collected at the base of Niagara Falls and to prevent or retard future erosion.

Water Projects. The Canada Water Conservation Assistance Act empowers the Government of Canada to provide financial assistance to the provinces in the construction of major works for the conservation and/or control of water.

During the year, the Division's activities were concentrated on the conservation and flood control of the Upper Thames Valley Conservation Authority and the Metropolitan Toronto Conservation Authority in Ontario, and on projects in North and West Vancouver, British Columbia. Similar service was provided in connection with the Greater Winnipeg Floodway which was virtually completed during the year.

A new development was the establishment of a joint Canada-Ontario task force to develop engineering and economic guide lines, criteria and standards for use in future river-basin developments in Ontario.

Engineering Hydrology. During the year, the Division investigated the causes of the recent high water on Lake Winnipeg, computed the average run-off for Canada as a whole and for the principal drainage basins, and studied flood frequency in Southern Ontario and in the Maritime Provinces. Calculations of the quantities of water capable of being handled by specific spillways were made for a number of potential water-project sites in northern Ontario, and flood characteristics of streams draining the eastern slopes of the Rocky Mountains were under study.

The Division provided technical advice to the Atlantic Development Board in connection with the Board's study of water resources in the Atlantic Provinces.

River-Basin Studies. Considerable progress was made on a study of the potential and the economic development of several river basins in northern Ontario. A full-time staff completed its second year on the study, formulating alternative development schemes, locating storage and diversion sites and designing and costing the required control structures. Reports are under preparation to show the water yield, the cost and the physical benefit for various alternative development possibilities.

In the Atlantic Provinces, a study of the Bay of Fundy tidal power is being conducted under an agreement between the Governments of Canada, New Brunswick and Nova Scotia. The first phase of the study involving the selection of alternative power sites has been completed and the second phase has been initiated. The Chief of the Engineering Division serves as chairman of the Engineering and Management Committee which is undertaking the technical and economic studies for the Atlantic Tidal Power Programming Board.

On the Prairies, the Government of Canada and the three Prairie Provinces initiated a study of the water resources of the Saskatchewan-Nelson River Basin including the additional supply that would become available through diversion or storage. The Division Chief is alternate to the chairman and a senior engineer of the Division is secretary of the board guiding the study, which is being carried out by a study director and staff located in Regina.

WATER QUALITY DIVISION

The Water Quality Division's main objective is the study of water and waste-water chemistry, water-treatment procedures and pollution abatement to promote the effective utilization of Canadian water resources. Its present activities include basin and regional water-quality studies, such as the operation of monitoring networks, research on sampling and analytical methods, and field and laboratory investigations and research on treatment processes for improving water quality. The Division also studies the prevention of corrosion from waters and waste waters, and the Division's laboratories provide analytical support to others undertaking research into and investigations of water problems.

The water-quality network, one of the Division's commitments to the International Hydrological Decade, was expanded during the year from 140 to 180 sampling stations on about 125 Canadian rivers. This network is being further expanded for analytical coverage at key points to provide additional information on pollution parameters and thus serve to some extent as a surveillance network. In addition, the Division extended its co-operation with provincial and federal agencies and universities on I.H.D. studies in research and experimental basins, increasing the number of studies from four to ten in various areas of Canada.

The Division extended its monitoring for toxic pollutants at base-metal mines in New Brunswick, daily sampling being established on several receiving streams. Monitoring was also initiated at one operating mine in the Northwest Territories. Research is under way on pollution from mining wastes, on better processes for treatment of acid waters, on ponding and neutralization techniques, and on the transport of sulphide-containing wastes by receiving waters and the role of bacteria, air, etc. in the production of acid waters.

The Division assisted consultants engaged by the Atlantic Development Board and the New Brunswick Water Authority on resources studies in the Atlantic Provinces, providing information on water quality and on pollution of waters by mining.

In western Canada, the Division continued its long-term survey of the quality of international waters, particularly those of the Pembina, Souris and Red River systems. To assist the Eastern Slopes (Alberta) Watershed program, surveys were continued on the quality of the headwaters of the Saskatchewan River system and the monitoring of receiving streams near Alberta coal mines. A number of smaller short-term surveys were carried out to assist various researchers, e.g., surveys on water quality in the Waterton National Park for the Department of National Health and Welfare and in the Crowsnest area for the Department of Lands and Forests, Province of Alberta. Studies of the Columbia River at the International boundary were made and a suitable location for continuous monitoring of this river selected.

Studies of the relationship between corrosion and water quality continued and research on the relationship between water quality and pitting corrosion of copper pipe was initiated.

Research on methodology was intensified, with major emphasis on the automation of methods for sulphate and for low concentrations of nitrogen and phosphorus and to the identification of organic pollutants by chromatographic and other techniques. Modest research on natural organic matter in waters is under way.

The Division continued to assist the Departments of National Defence and Public Works on boiler-water treatment and to provide technical assistance to provincial and other public and private agencies on water quality and treatment.

The Division set up a small laboratory at the Canada Centre for Inland Waters at Burlington to carry out analyses and related work both on shore and aboard ship in support of research on the Great Lakes. Staff and equipment at this laboratory have been increased to provide analytical support for two research vessels during the coming year.

Work continued on data-processing systems to provide computer storage, retrieval, and print-out of analytical data. A desk computer is now in operation for rapid processing of analytical results in the laboratory. Every effort is being made to make the system compatible with data and publications of other divisions and with data obtained from other agencies, particularly provincial agencies.

The Division maintained its liaison with national and international organizations and co-operated with Committee D19 of the American Society for Testing and Materials and with the U.S. Department of Health, Education and Welfare (Public Health Service) on research connected with methods of analysis.

The Division will be moving from Ottawa to the Canada Centre for Inland Waters at Burlington within about three years. Much of the initial planning for laboratories and pilot-plant facilities at the Canada Centre has been completed, but these facilities must be available before a number of major applied and engineering research projects on pollution abatement can proceed.

ENERGY DEVELOPMENT GROUP

The Energy Development Group examines Canada's total energy sources and requirements, with the Assistant Deputy Minister serving as senior adviser on overall energy plans and policies. This total energy concept is imperative at this time when there are many changes taking place in the energy area; the shifting from a predominantly hydro-electric supply to a thermal-electric and nuclear base; the development of new sources of oil and gas and extensive exploration in the far north and on our continental shelf; the reactivation of our uranium industry to meet the growing world demand for nuclear energy; and the development of large markets to permit the economic development of our vast western coal reserves. These conditions cannot be considered in isolation if the maximum benefits are to be developed for Canadians. Co-ordinated development policies and research programs must be established and fostered, and this is the task now facing the Department of Energy, Mines and Resources.

An Assistant Deputy Minister (Energy Development) was appointed on July 1, 1967, and began to organize the Energy Group. Senior advisers will be selected to head branches concerned primarily with electrical energy, oil and gas, and solid fuels (uranium and coal). In addition to the new advisory staff required for these branches, two transfers of existing energy-oriented units are proposed. An internal departmental transfer of the Resource Administration Division which, among other duties, has the responsibility for offshore oil and gas resources, has been approved; and absorption of the staff and functions of the Dominion Coal Board is contemplated following approval of legislation to dissolve that board.

ELECTRIC ENERGY

Atlantic Provinces Power Development Act. This Act is presently administered by the Northern Canada Power Commission which, in this responsibility alone, reports to the Minister of Energy, Mines and Resources. In addition to a general review of all APPDA matters for the Minister, the Energy Group participated in the following:

(a) An interdepartmental review of a submission by Maritime utilities seeking financing under the Act for thermal-electric power development as well as transmission facilities.
(b) A joint study by the Newfoundland Power Commission and the federal government to establish the relative economics of alternative means of satisfying Newfoundland's future power needs.

Atlantic Tidal Power Study (Bay of Fundy). The Group maintained a general review of progress during the year on this federal-provincial endeavour and participated in studies concerning the matching of power generation to market conditions in the United States and Canada. The Group is represented on the Engineering and Management Committee which is carrying out the study.

Saint John River Treaty. While this draft treaty for joint U.S.-Canada development of the Saint John River remained relatively dormant during the year, liaison was continued with United States, New Brunswick and Quebec officials.

Nelson River Development. An informal liaison was maintained with Manitoba Hydro and Atomic Energy of Canada Limited to follow the progress on the federal-provincial Nelson River Agreement. The Review Committee called for by the agreement will be established in the coming year. The committee is to provide annual reports to the two governments on the progress being achieved on the transmission facilities being constructed by AECL and the power-generating facilities which are the responsibility of Manitoba.

Columbia River Development. The Assistant Deputy Minister continued his duties as Canadian chairman of the international Columbia River Treaty Permanent Engineering Board which is charged with ensuring that the objectives of that Treaty are met. The board submitted its last annual report to the Canadian and United States Governments in December of 1967.

Numerous studies relating to construction and operation of the Canadian Treaty projects of Arrow, Duncan and Mica were reviewed or carried out by the board staff (Canadian section) in Vancouver, B.C.

The Assistant Deputy Minister also continued as federal chairman of the B.C.-Canada Columbia River Advisory Committee which assists a federal-provincial committee of ministers to facilitate implementation of the treaty by Canada. The federal chairman of the ministerial committee is the Minister of Energy, Mines and Resources.

Trans-Canada Grid Study. The Group prepared the final report of the Federal-Provincial Working Committee on Long-Distance Transmission. This study was initiated in 1962 at the request of a ministerial committee representing the federal and nine provincial governments. The report of the working committee has been distributed to all participating governments and is ready for tabling in Parliament.

The working committee continued to follow closely the development of transmission facilities in Canada and discussed with utilities transmission developments which could improve the chances for the inter-provincial or international flow of electrical energy.

Research. The advent of long-distance high-voltage direct-current transmission in Canada for the Nelson River development has prompted interest in the development of solid-state equipment for the conversion of alternating to direct current for transmission and back to alternating current for distribution. A survey of possible direct-current applications in Canada over the next 13 years was made to assess the domestic market for such equipment. Research has been discussed with Canadian industry and the Department of Industry and the possible test-sites were selected.

OIL AND GAS

A continuing review of domestic and international oil and gas developments and market trends was carried on; however, the group's activities in this field of energy were restricted pending staff recruitment. The Group participated in appraisals of the Panarctic exploration program for the Arctic Islands in which the federal government participates; and the Point Tupper, Nova Scotia, refinery which is being established with federal

assistance as a means of encouraging the development and diversification of the economy on Cape Breton Island. The large Point Tupper refinery is looked upon as a cornerstone for petrochemical and related industries, and it will have the benefit of a deep-water port capable of handling the super-tankers of the future.

(Jurisdiction over offshore exploration on the Atlantic and Pacific coasts and in Hudson Bay is exercised by the Resource Administration Division. During the period covered by this report, that division operated within the Mineral Resources Division of the Mineral Development Group, and its activities will be found covered under that heading. In future, reports on the Resource Administration Division will be found under the heading of Energy Development, to which Group it is being transferred.)

COAL AND URANIUM

The Group participated in interdepartmental work concerned with the rationalization of the Cape Breton coal industry. The establishment of the Cape Breton Development Corporation, a Crown corporation, to administer the coal mines and encourage the development of a more diversified economy on Cape Breton Island, marks a new approach to the solution of problems caused by changes in the pattern of energy production and consumption.

Arrangements were made with the New Brunswick government for a new form of assistance to the Minto coal field that will make coal production more efficient and thus reverse the gradual loss of markets.

With greatly increased activity in the uranium industry, attention is being directed towards Canada's uranium prospects. Canada is one of the leading sources of uranium in the world and is expected to play an important role in meeting the world's requirements for this new source of energy. In anticipation of greatly increased exploration, the Group joined the Atomic Energy Control Board and provincial departments of mines in planning regulations governing exploration for uranium in Canada.

Notes
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DEPARTMENT OF
ENERGY, MINES AND RESOURCES
OTTAWA, CANADA

annual report 1968-69

Hon. J. J. Greene, Minister

CANADA

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CANADA
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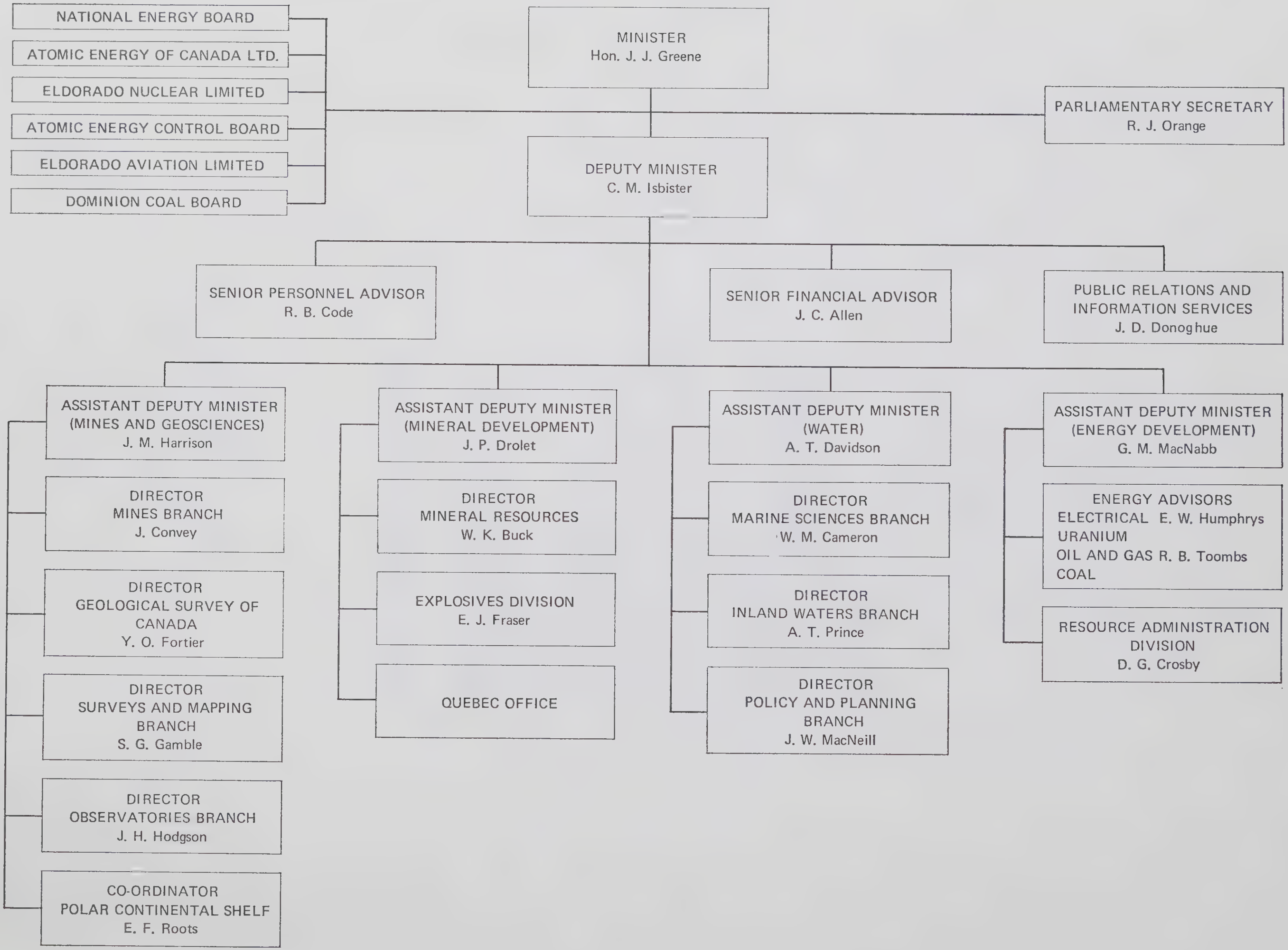

INTRODUCTION

The Department of Energy, Mines and Resources is the federal government's principal agency for the discovery, investigation, development and conservation of the nation's mineral, water and energy resources. It carries out geological, hydrographic, oceanographic, geophysical, hydrologic, geodetic and topographical surveys, engages in mineral and metallurgical research, both technological and economic; assesses and helps to plan the distribution of water and energy resources; and carries out a number of policy-making and administrative tasks affecting Canada's resources and the industries associated with them.

The Department is housed mainly in Ottawa, with several research establishments in other parts of Canada, chiefly in British Columbia, Alberta, Ontario, and Nova Scotia.

This report covers the fiscal year April 1968 to March 1969.

The largest group within the Department, in terms of personnel, is the Mines and Geosciences Group, consisting of the Surveys and Mapping Branch, the Geological Survey of Canada, the Mines Branch, the Observatories Branch, and the Polar Continental Shelf Project. Both the range of activities and the information disseminated by these technical and scientific organizations reached new levels during the year under review. The Surveys and Mapping Branch's Geodetic Survey put 31 parties into the field to extend or increase the density of the existing national survey framework for mapping and charting, municipal control and engineering projects. The last of the field control required for the 1:250,000 mapping of Canada was established on islands in northern Hudson Bay by parties working from icebreakers. These islands had previously resisted all attempts at surveys, owing to pack ice or fog. The Topographic Survey forwarded for reproduction a record number of 657 National Topographic Series maps. This high number of clearances was reached through a high rate of production. Compilation for the islands in Hudson Strait noted above completed mapping at the 1:250,000 scale, and in future that series—a monumental achievement in the mapping of Canada—will only have to be revised from time to time. The Air Photo Library filled a record number of 7,324 requisitions, covering 844,568 prints from air-survey negatives.

The Geological Survey of Canada sent about 100 full-season parties into the field in all parts of Canada. Two large helicopter-supported projects, one in northeastern Baffin Island and the other in northwestern District of Mackenzie, resulted in the completion of reconnaissance studies of an area measuring 153,000 square miles. The Mines Branch continued a large number of experimental projects designed to assist the Canadian mineral industry in achieving more effective or economical operations. A complete system for the electrochemical determination of soluble oxygen in molten steel, for use in steel plants, was devised and made ready for industrial trials. The resurgence of industrial production in Japan has led to a tremendous demand for coking coal in that country. To ensure that western Canadian coal producers will reap the full benefits of this expanding market, the Fuels Research Centre has improved and modernized its facilities for evaluating coking coal, along with its equipment for the experimental processing of coal. Over half the ore mined in Canada comes from open pits, and considerable research at the Mines Branch is devoted to the theoretical design of the best pit slopes and other engineering factors. Further progress was made in the development of an advanced metallurgical furnace, combining gas, oil, and electricity as heat sources.

During the year the Observatories Branch made plans for redesigning its Mirror Transit Circle, an instrument intended to measure star positions and the rotation of the earth. Meanwhile, the Branch inaugurated its Photographic Zenith Tube Observatory at Calgary on May 18, 1968, with scientific representation from the United States and Britain. The Meteorite Observation and Recovery Project (MORP) established its headquarters at the University of Saskatchewan. The Dominion Radio Astrophysical Observatory at Penticton teamed up with an observatory in Saskatchewan and one in Australia to conduct a long-baseline-interferometer experiment to determine the angular diameters of quasars. The Dominion Astrophysical Observatory at Victoria observed its 50th anniversary, in honour of which the American Astronomical Society held its 127th meeting in that city.

Although the federal government has halted expenditures on the proposed 156-inch optical telescope on Mount Kobau in British Columbia, it has agreed to turn over existing equipment to a consortium of western Canadian universities, which hope to bring the project to fruition. Collaboration is being extended by the Observatories Branch. In the field of geophysics, the Branch moved its geomagnetic observations to a new laboratory on the eastern outskirts of Ottawa, where environmental conditions are expected to be excellent for a long time to come.

The Mineral Resources Branch, mainstay of the Mineral Development Group, carried out a series of fundamental regional studies designed to serve as guides to economic redevelopment in the Atlantic region and elsewhere. It provided advice to the government on numerous matters concerning Canada's mineral industry, and continued the publication of its studies on the production and trade of Canadian minerals. The Roads to Resources program, administered by the Branch, was nearing completion, with the remaining $350,000 (out of a federal share of $75,000,000) committed for completion in 1969-70.

In the Water Group, the Marine Sciences Branch expanded its survey fleet with the commissioning of CSS *Limnos*, a vessel designed for research on the Great Lakes. Design, specifications and contract drawings were completed for a second such ship. At the Bedford Institute in Dartmouth, N.S., considerable construction went on during the year, including the extension of the jetty, the expansion of the laboratory wing, and the addition of two more floors to the office wing. The Hydrographic Service distributed a record number of charts—309,200. A highlight in oceanography was the cruise "Hudson Geotraverse," which followed a one-degree-wide strip from Cape Breton Island to the Mid-Atlantic Ridge; it was expected to yield fundamental data on the formation of deep ocean basins. The Policy and Planning Branch and the Inland Waters Branch continued to expand their role among bodies planning and administering resources in Canada, as evidenced by their participation in, or contributions to, such agencies as the Interdepartmental Committee on Water, Canadian Council of Resource Ministers, Interdepartmental Committee on Resources, Joint Program Committee of the Canada-British Columbia Agreement for Studies and Flood Control in the Lower Fraser Valley, Canada-Ontario Committee on the Canada Water Conservation Assistance Act Programs, Northern Ontario Water Resources Study, Steering Committee for the International Field Year on the Great Lakes, International Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, International Columbia River Treaty Permanent Engineering Board, Groundwater Observation Well Network, Canadian National Committee of the International Hydrologic Decade, Saskatchewan-Nelson Basin Board, boards of control for the Great Lakes, and numerous others.

The Energy Development Group participated in planning and discussions looking toward the expansion of Canada's energy network, notably in the field of electric power. It advised other departments of the federal government on oil and gas policy and prepared to take over the remaining responsibilities of the Dominion Coal Board, which is to be dissolved with the phasing-out of subventions. The Canadian coal industry was being encouraged to establish an industrial organization to act on its behalf in maintaining effective liaison with the federal government. The Resource Administration Division noted expenditures of over $18 million by the oil industry in Canada on oil and gas permits for offshore exploration during 1968, an increase of about 38 per cent over the previous year. The past fiscal year also saw the establishment by the federal government of "mineral-resource administration lines" in Canada's offshore areas, dividing federal and provincial jurisdiction in that field.

MINES AND GEOSCIENCES GROUP

Surveys and Mapping Branch

The past fiscal year has seen the re-arrangement of the operating units of the Surveys and Mapping Branch into the major groupings of Field Survey, Aerial Survey and Map Production. In organizing all units of the Branch into groups, each with a common general purpose, it was obvious that those concerned with field surveys should be in one group, those concerned with air photography and photogrammetry in a second, and those concerned with the production of maps in the third. This re-assembling was accomplished without extinguishing the names of units such as Topographical Survey and Geodetic Survey that had served Canada continually for the past 60 years.

The Field Survey now embraces Legal Surveys, the Geodetic Survey, and the International Boundary Commission; the Air Survey embraces the Topographic Survey and the National Air Photo Library; and Map Production embraces Cartography, Air Charts, Geography, Toponymy, and actual Map Production.

FIELD SURVEY DIRECTORATE

Geodetic Survey

Thirty-one field parties established horizontal and vertical control to extend or increase the density of the existing national survey framework for mapping and charting, municipal control and major engineering projects. In addition the Survey continued and expanded its activities on investigational projects.

The extension and strengthening of first-order horizontal control was carried out in the Northwest Territories and six provinces. In the Northwest Territories and Alberta a team cooperated with the Topographical Survey on the aerodist control project. In British Columbia a network was extended north up Kootenay Lake to Revelstoke, thence west to connect with existing surveys near Salmon Arm, closing a large loop; from Revelstoke a new network was extended east to Golden and a spur net run from Golden north to Mica Dam. In Alberta, scale control was established in the existing network between Suffield and Calgary. New networks were established in Ontario from Chatham to Windsor and from Chatham to Sarnia. In northern Quebec, triangulation was extended south from Great Whale River to Fort George and thence southeast to connect with existing triangulation at the north end of Mistassini Lake, closing a large triangulation loop. In the Quebec City area a long-term program for increasing the density of and extending first-order surveys was started. This program will cover the economically important areas of southern Quebec, and is being carried out in cooperation with the Quebec Department of Lands and Forests. A dense first-order network was established in Prince Edward Island to provide the framework for a plane-coordinate survey system which will cover the entire province. A re-survey of the Magdalen Islands was carried out to replace destroyed stations and to connect Hydrographic Service control stations.

First-order levelling was carried out in seven provinces. The Trans-Canada level line was extended eastward from Kamloops, B.C., through Alberta and Saskatchewan to the Manitoba border. In the course of this operation, vertical control networks were established in Banff, Lethbridge, Red Deer and Medicine Hat in Alberta. Re-levelling was carried out in the vicinity of Bennett Dam in northern British Columbia to check crustal movements. Levelling of high precision, using the metric system, was carried out between Kingston, Ontario, and Beauharnois, Quebec with five connections made to United States Lake Survey bench marks on the south side of the St. Lawrence River. This work is a part of the program for the re-evaluation of the International Great Lakes Datum, 1955. Elsewhere in Ontario, water crossings were made to connect Wolfe and Howe Islands, near Kingston, to the national framework, and the area levelling in the southwest quadrant of the National Capital area was completed. In Quebec a new line was completed from Fugereville to Guérin and forty water gauges were tied in along the St. Lawrence River to check bench mark stability. In New Brunswick, lines were run from Woodstock to Saint John on both sides of the Saint John River, from

Hartland to Saint John and from Sussex to Riverside. Many water gauges were connected in the course of this work.

Five astronomic parties worked in seven provinces. One Laplace point and twenty deflection stations were established in the Kootenay-Revelstoke area of British Columbia. Two Laplace points and one deflection station were established in Alberta, one Laplace point in Ontario. In Quebec two Laplace points and one deflection station were established and in the Maritimes three Laplace points and six deflection stations were established.

The aerodist program was continued and an extensive area was controlled in northern Alberta and extending into the Northwest Territories to Yellowknife and Fort Simpson. A large part of the area is under intensive oil exploration, and this survey provided the control for 1:50,000 mapping as well as the necessary geodetic framework surveys to aid in development. An area of 150,000 square miles was controlled. At the close of the aerodist operation an experimental project was undertaken in priority areas during September to supply additional framework control of lesser precision, to assist in locating sites where oil exploration is active. This operation used the *Autotape,* a new electronic airborne survey method to extend control points into very difficult terrain.

Another long-term project, the tellurometer traversing in the western Cordillera to provide control for 1:50,000 mapping and in support of the Observatories Branch gravity survey, was continued. A Topographical Survey party extended control through an area of 10,000 square miles in southern British Columbia while a party from the Mapping and Charting Establishment controlled an area of 26,000 square miles.

Assistance to provincial and municipal authorities in establishing coordinate systems of control surveys continued to be a major effort. Work was carried out in British Columbia at Vancouver-Burnaby and in Nova Scotia in the Port Hawkesbury area of the Strait of Canso, Antigonish and Amherst. In Ontario, two parties worked at extending coordinate systems in Chatham, Windsor, the Niagara Falls area, St. Catharines, and along Highway 401 and Highway 3. A third party was engaged in municipal levelling in Barrie, Woodstock, Kitchener, Waterloo and Guelph.

Three parties were engaged in establishing field surveys to control 1:25,000 mapping at Halifax, Chatham, Ontario, and Calgary.

Two parties supplied field surveys for 1:50,000 mapping near Fredericton and Woodstock in New Brunswick and near Nipawin, Saskatchewan.

The last of the field control required for 1:250,000 mapping was established on islands in Northern Hudson Bay by a party working off the icebreakers CGS *Labrador* and *N. B. McLean.* These islands had previously, because of pack ice or fog, resisted all attempts at mapping surveys.

One party completed a winter levelling project during February and March 1969, covering about 285 miles between Winisk Lake and Sakwaso Lake in northern Ontario. This work was needed to provide more accurate vertical information for water-resources research in that area.

Legal Surveys

The main work of the Division, as usual, was its legal surveys in Indian reserves, national parks and territorial lands. Once again the largest project was on the Caughnawaga Reserve where approximately half of the large Indian village and 800 acres of farm land were resurveyed and subdivided.

The Division had 16 survey parties in the field and, in addition, arranged contracts with 43 private survey firms to complete as many as possible of the projects required for federal government departments. They worked on projects in 122 Indian reserves and in six national parks. Technical instructions were issued for some 200 surveys on Crown Canada Lands for provincial and private interests.

In the Territories, the largest projects were residential and industrial subdivisions at Frobisher Bay and Baker Lake, but smaller miscellaneous surveys were made at 12 other settlements in the Northwest Territories as well as in the Whitehorse area of the Yukon. The control network at Carcross was completed.

Two commissions for interprovincial and territorial boundaries were active in this period. The resurvey of the southerly 240 miles of the Manitoba-Saskatchewan boundary was continued and approximately 51 miles of trial line was completed. Preparation for the maintenance survey of the British Columbia-Yukon Territory-Northwest Territories boundary was begun.

Survey documents entered in the Canada Lands Surveys Records numbered 1,633 plans and 211 field books, some 1,000 of the former being plans previously stored in the Mining Recorder's office at Dawson.

About 55,000 document extracts and astronomical field tables were despatched and information on 443 airline distances was supplied for official purposes.

The Board of Examiners for Dominion Land Surveyors met eight times. Of the thirty candidates who sat for part of the 1969 annual examinations, three completed the preliminaries, three the intermediates, and three the finals to qualify for the D.L.S. commission. One candidate was granted his certificate as a Dominion Topographical Surveyor.

International Boundary Commission

During the 1968-69 fiscal year, the Boundary Commissioner for Canada and the Commissioner for the United States made joint inspections at various points along the line and inspected the work of field parties on several sections of the boundary.

Three Canadian field parties carried out work on the Quebec-Maine, the Ontario-Minnesota, and the British Columbia-Washington boundaries.

The task of controlling growth along the 20-foot boundary vista was greatly relieved by the introduction of power spraying equipment mounted on a tracked motor vehicle. This newly developed equipment was used to complete herbicide treatment on 108 miles of Quebec-Maine boundary. An additional 15 miles of heavy growth were recleared along the height-of-land boundary.

On the Ontario-Minnesota boundary, resurveys were commenced on Lake of the Woods and through Rainy River, to re-establish reference monuments which were lost or moved through erosion or construction operations, and to improve the overall accuracy of the original boundary surveys in that area.

The program of maintaining the 400 miles of mountainous vista along the 49th-parallel boundary by aerial applications of herbicides was continued during the field season. Chemicals were applied by helicopter to 60 miles of 20-foot vista through forest sections of international boundary from the Fraser Valley to the Okanagan Valley.

Altogether Canadian parties recleared 15 miles of boundary vista, treated 168 miles with chemicals, inspected 432 monuments (of which 40 were repaired and 17 reconstructed in new locations) and determined new geographic positions for 47 monuments and other markers.

AIR SURVEY DIRECTORATE

Topographic Survey

During the past year, the Topographic Survey Division forwarded for reproduction a record number of 657 National Topographic Series maps. This high number of clearances was reached because of a continuing high rate of production, together with a concerted effort to reduce the number of maps in post-compilation phases and an acceleration of the revision of out-of-date maps.

Eighty per cent of our production of maps was at the 1:50,000 scale. The square mileage depicted on maps cleared for reproduction in this series increased by over 100 per cent, although the number of maps (533) increased by less than 20 per cent. This was due to the change of format of the popular 1:50,000 scale map from 15 x 15 minutes to 15 x 30 minutes.

Compilation for several islands in Hudson Strait completed the new mapping at the 1:250,000 scale, and the task in this series is now one of revision. Nineteen sheets at this scale were passed forward for reproduction. New and revision mapping in the 1:25,000 series of maps increased to a total of 105 maps, an increase of about 400 per cent over the best previous year.

Under agreement, this Department reproduces the 1:50,000 maps compiled by the British Columbia Department of Lands, Forests and Water Resources. The Topographical Survey reviewed 25 British Columbia maps in this series prior to clearance from reproduction. The Mapping and Charting Establishment, Department of National Defence, also assisted in production of National Topographic Series mapping by the compilation of eight maps at 1:50,000 for training purposes.

Photomaps produced as map substitutes are meeting wide acceptance. During the past year, 75 photomaps at 1:50,000 were produced and an additional 75 at larger scales.

In the field of research and development, the development of a set of computer programs for the three-dimensional adjustment of large photogrammetric blocks was finished during the past year. This system was used for the first time for the production of maps in November 1968, and had completely replaced the old system by the end of the year. The new system eliminates a large number of manual operations and considerably speeds up the adjustment phase of the aerotriangulation. Another computer program to level

stereoscopic models analytically with the use of lake surfaces or equivalent vertical information was completed. This program was developed specifically for photogrammetric processing of aerodist photography.

National Air Photo Library

During the period under review, 7,324 requisitions for photographic work, the highest annual total in the Library's history, were prepared for processing. These requisitions covered 844,568 prints from federal government air survey negatives (contact prints, enlargements, diapositive mapping plates, lantern slides, transparencies, etc.). This represents an increase of more than 10 per cent over the previous year in the number of requisitions raised and prints provided. The Library also processed 174,917 black-and-white photographs, 958 colour photographs and 166 mosaics (MG series) in connection with maintaining a file copy of each set of photographs produced by or for the federal government in the mapping of Canada. This brought the total of the Library collection to over 3,325,400 black-and-white prints, 13,492 colour prints, 24,000 uncontrolled (RE) mosaics and 982 semi-controlled (MG) mosaics. Many new services and products are being provided, largely in response to requests for colour, "false colour" (infrared) and the products of remote-sensing systems. This has placed an additional strain on production facilities that is not fully revealed by production figures.

In September the National Air Photo Library officially opened to the public its Western Branch (Calgary) Air Photo Library. This Library is located in the building of the Institute of Sedimentary and Petroleum Geology in Calgary. Since its opening to the end of the period under review, this branch office has raised 164 requisitions requesting 31,173 prints of federal government negatives held in Ottawa, and has received from Ottawa approximately 500,000 prints for local inspection by clients.

MAP PRODUCTION DIRECTORATE

Cartography

The Division carries out the finished drawing of all topographical maps and special maps produced by the Branch. Maps received from the Air Survey Directorate for reproduction numbered 657. Derived map compilations produced by the Division totalled 169; these included 43 air-chart bases, 8 topographical maps, 118 regional and special-purpose maps. Drafting production for the year totalled 479 completed jobs; these included 49 at 1:25,000, 278 at 1:50,000, 8 at 1:125,000, 27 at 1:250,000, 10 I.M.W. sheets, 29 air-chart bases and 78 miscellaneous drawings. The new *Atlas and Gazetteer of Canada* was forwarded to the Queen's Printer for reproduction in French and English.

At the end of the fiscal year the status of the 1:50,000 series stood at 28 per cent published, with 3,663 sheets now in print of the potential 13,150. The status of the 1:250,000 series stood at 99 per cent published, or 909 of a potential 918.

The conversion of the 8-mile series to 1:500,000 is now 96 per cent complete, with 210 in the new format of the total 219.

Map Reproduction

The map printing during the past year included 821 topographical maps, 276 air charts, 16 wall maps and special sheets, 762 maps and charts for other branches of the Department and 217 maps and charts for other departments—a total of 2,092 maps and charts printed.

Aeronautical Charts

Forty-seven different series of charts and flight-information publications were maintained, with 116 new charts added to the series. Twenty-two new radar-surveillance charts were produced. The first issue of a *Canadian Flight Planning and Procedures Manual* was published; it is to be revised every 105 days.

Geography

Twenty-five per cent of the *National Atlas of Canada* was processed beyond the editorial and translation stages during the year. The cartographers are preparing these sheets for publication in French and English. The Division produced three special sheets during the year. The Urban Analysis Series, a joint project between the Emergency Measures Organization and the Surveys and Mapping Branch, was cancelled in 1968. The Division continued to examine methods of computer analysis and display of special information and computer graphics suitable for thematic mapping. Cooperation with the Department of National Health and Welfare resulted in the production by the latter of an experimental *Atlas of Hospital Utilization in Canada*.

Toponymy

During the fiscal year 1968-69 the Division investigated approximately 20,000 names and approved 3,500 new names. The geographic nomenclature for 387 maps was verified and approximately 120 inquiries involving significant research in the Division's records were answered. A new edition of the *Gazetteer of Manitoba* was issued in 1968. The revision of the *Gazetteer of Saskatchewan* was forwarded for reproduction early in 1969, and work on the first edition of the *Gazetteer of Quebec* brought it to the final stages.

Comprehensive study of the toponymy of New Brunswick started in 1967 and was almost completed. The Map Library dealt with 1,467 inquiries, loaned 972 maps, atlases and gazetteers to departmental agencies and others concerned with map production and cartographic research. It acquired 5,303 new maps and 105 gazetteers and atlases during the year.

The 1968 annual meeting of the Canadian Permanent Committee on Geographic Names was held in Edmonton.

BRANCH FUNCTIONS

Map Distribution

The number of maps and air charts distributed to civilian clients during the year rose to 2,162,000, marking the first time in the history of the Surveys and Mapping Branch or its predecessors that distribution has exceeded two million. Map distribution to the Canadian Armed Forces remained relatively steady at 1,500,000.

A statistical study of civilian map use in Canada was made during the past year. The following tables illustrate some of the interesting results of this study.

Map Use by Province

	Per cent
British Columbia	13
Alberta	17
Saskatchewan	5
Manitoba	6
Ontario	17
Quebec	23
New Brunswick	6
Nova Scotia	4
Prince Edward Island	1
Newfoundland	3
Yukon	3
N.W.T.	2
	100

These figures do not include maps used by other federal agencies.

Map Use by Occupation or Industry

	Percentage of Orders	*Percentage of Maps*
Federal Government	7	23
Provincial Governments	6	19
Industry and Commerce	5	3
Schools	9	5
Universities	6	7
Outdoor Sports	12	3
Engineering and Scientific	11	7
Air Navigation	20	16
Tourist Industry	4	2
Retail Sales	10	13
Use Unknown	10	2
	100	100

Map Use by Scale

Series		*Percentage of Distribution*	*No. of Sheets Published*
1:25,000		1	538
1:50,000		50	3,663
1:125,000		2	149
1:250,000		23	909
1:500,000	Base Map	2	226
	Air Chart	9	226
1:1,000,000	Base Map	1	68
	Air Chart	2	68
Other Maps		10	1,253
		100	7,100

Interdepartmental Committee on Air Surveys

The Interdepartmental Committee on Air Surveys carried out air photography in all provinces and territories to meet requirements from 14 federal departments and agencies. The increase in the use of colour photography by the technical community continues. "False colour" (colour film exposed through infrared filters which produce unnatural colours such as red for healthy vegetation, yellow for dead vegetation etc.) is also being used to a greater extent, especially by agriculturists.

Technical Aid Section

The Surveys and Mapping Branch continued to provide technical advice and engineering support to the Canadian International Development Agency (formerly External Aid Office) in topographical mapping projects in Tanzania, Nigeria, Trinidad and Tobago, Guyana

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and Jamaica. It also provided practical training in surveying and mapping techniques to students from developing countries attending Canadian technological institutes and universities. One such course, a 12-week seminar, was attended by students from Africa and from Commonwealth countries of the Caribbean.

The annual meeting of the federal and provincial survey directors was held in Edmonton, Alberta. The meeting decided on a review, being carried out by G. S. Andrews (formerly Surveyor General of British Columbia), of the administration of surveying and mapping in Canada.

Geological Survey of Canada

The Geological Survey is responsible for providing geological information, concepts and techniques to assist in the evaluation of the nation's potential mineral resources, in the search for mineral deposits, and in the planning by industries and federal and provincial agencies concerned with renewable and nonrenewable resources of northern and regional development, land use and engineering projects. The Survey investigates, describes, and explains the geology of Canada, including continental shelves, provides a national and regional geological framework including correlation of geological knowledge between regions or provinces through total or partial survey related to the capability of the province concerned, and provides a research-and-study competence in various specialized disciplines. Through this latter function the Survey maintains standards appropriate to the systematic investigation of the geology of Canada, investigates problems such as the properties, identification, classification and origin of minerals, ores, fossils, structures, and landforms, and provides a national cadre of specialists available as a source of expertise to various federal and provincial government agencies, to industry, and to the general public. The Survey also examines theories, develops and tests new instruments and methods, and performs pilot projects and surveys as aids to geological research and the search for mineral deposits. The results of the studies carried out by the Geological Survey are disseminated to users through extensive independent publication, through scientific, professional and trade journals and conferences, official communications, and participation in national and international scientific conferences. The Survey maintains libraries and collections of books, oil-well cores and samples, mineralogical and paleontological specimens for reference by its own staff, by other government agencies and by industry and provides geological information to the general public, tourists, hobbyists and educators.

During the report period the Branch had 505 active projects of which 213 had a field component. There were 223 project leaders including four postdoctoral fellows, eight university professors and 20 seasonal employees.

In 1968-69, there were 67 graduate assistants employed in the field and 23 in the office; 108 student assistants were attached to field parties and 42 were assigned to office duties.

During the 1968 field season about 100 full-season field parties conducted studies in all parts of Canada. Two large helicopter-supported projects, one in northeastern Baffin Island, the other in northwestern District of Mackenzie, resulted in the completion of reconnaissance studies of an area of 153,000 square miles. The activities of the smaller parties ranged from studies of the Pacific Continental Margin to the development of geochemical techniques applicable to mineral exploration, from studies of landforms in the Arctic to hammer-seismic surveys to aid in the mapping of surficial deposits, and from detailed studies of Precambrian rocks to stratigraphic studies of Paleozoic and Mesozoic rocks necessary to solve problems affecting petroleum exploration.

To stimulate and support research in the geological sciences at Canadian universities, 112 grants totalling $220,000 were made to 24 universities; in addition five special grants totalling $43,000 were made to five universities for research in the development of computer-processable files of geological data.

The scientific results of the Survey's research are published in a variety of forms designed to fit user need and the nature of the material. During the report period, 6 memoirs, 10 bulletins, 2 economic geology reports, 2 miscellaneous reports, 67 papers and 18 geological maps (excluding those used to illustrate the preceding reports) were issued under Survey auspices. In addition, staff members published 138 technical

papers in a wide range of outside journals. These varied from one-page notes on subjects of current interest to a 584-page textbook. Sixty-eight scientific papers were presented at major technical meetings held in Canada and abroad, 49 talks were given to graduate seminars and smaller technical groups and staff members participated in the presentation of six university courses.

About 367,000 items were distributed, mainly from the Ottawa office but about 10 per cent through the Survey's Institute of Sedimentary and Petroleum Geology in Calgary and a lesser amount through the Branch's Vancouver office. The library had a circulation of about 39,500 items during the report period. The staff handled 8,370 inquiries, of which 1,650 required information searches, an increase of nearly 40 per cent in this particular aspect of the library's work.

In addition to the headquarters in Ottawa the Survey maintains an office in Vancouver, and the Institute of Sedimentary and Petroleum Geology in Calgary. A resident geologist was stationed at Whitehorse throughout the year and another at Yellowknife until early February 1969.

CRUSTAL GEOLOGY

The prime objective of this division is to study and interpret the folded, metamorphosed and igneous rocks that form the earth's crust beneath Canada in order to provide the basic geological data required to forecast, discover and evaluate Canada's mineral resources and to provide scientific knowledge on the origin and historical evolution of the crust.

Nineteen field parties carried out studies in the Canadian Shield, four in the Appalachian region, 13 in the Cordilleran and Pacific Margins area, four in the field of petrology and one in the field of Eastern Canadian paleontology and three in coal research. In addition numerous office and laboratory studies, many based on earlier field studies, were carried out.

The major project carried out in the Canadian Shield, "Operation Bylot", resulted in the mapping at the scale of 1:250,000 of 53,000 square miles of northeastern Baffin Island, part of which contains the large potential iron-ore deposits of Baffinland Iron Mines at Mary River. Studies of specific Precambrian geological problems included those made of the Hurwitz and Hornby Bay groups, a study of volcanic rocks in the Seal Lake area, Labrador, which is part of a continuing study of volcanic rocks in the Precambrian Shield, and mapping of several 1:250,000 map-sheets in Manitoba, District of Keewatin, and Newfoundland.

In the Cordilleran region, detailed studies of the important Anvil base-metal deposit were completed and a study of the northern coastline of Vancouver Island was commenced. As most of the Survey's personnel connected with Cordilleran geology are in Vancouver, the office there is frequently visited by mining people, and during the period covered by this report there were 11,440 callers.

Members of the Appalachian, Eastern Lowlands and Atlantic Margins section study the composition, stratigraphy and structure of post-Precambrian rocks in these areas (including Hudson Bay Lowlands) to evaluate potential mineral and petroleum resources. Field investigations were carried out in Botwood and the Straits of Belle Isle, Newfoundland, in Antigonish area, Nova Scotia and at Tuadook Lake map-area, New Brunswick. The latter area is of interest because it lies in a belt that contains the Bathurst mining camps.

Members of the Petrology Section continued studies of specific rock types designed to provide a means of elucidating petrologic problems of economic or regional significance. They also carry out research on extraterrestrial materials and maintain the National Mineral Collection. The section operates the Petrology Laboratory which provides special petrographic services for staff members and identifies rock specimens for the public.

The Geochronology Section develops facilities for isotope geology, and coordinates the Survey's age determinations and stable-isotope investigations. During the report period new laboratory facilities became fully operational and additional potassium-argon extraction lines have been assembled, thus providing the opportunity for experimental studies with terrestrial and oceanic basalts less than one million years old. Such data may be important in answering the question "have the continents drifted apart?"

The Coal Research Section is responsible for microscopic investigations of Canada's coals and associated clastic sediments in the fields of coal petrology and palynology, thus providing information valuable for coal geology, coal mining and coal utilization. In the period under review, studies of coal rank, environmental and facies studies of coal, research on coking coals, and investigations on the uranium possibilities in lignite were carried out as were studies of fossil pollen and other spores designed to support other geological studies.

Paleontological studies in eastern Canada are carried on under the auspices of this division, and during the report period members of the Eastern Paleontology Section prepared 50 reports on 449 lots of fossils. Those identifications are used primarily by other staff members to solve problems of correlation. The section was visited by geologists from universities, oil companies and other countries who examined collections and consulted with staff members. In Canada and other countries more than 20 experts on particular groups of fossils are studying Geological Survey material collected from eastern Canada for the Branch.

EXPLORATION GEOPHYSICS

This division conducts and administers geophysical surveys in Canada and over the adjacent continental shelves as an aid in geological mapping. Members of the staff also devise and test-run instruments for geophysical mapping, prospecting and other geophysical investigations and develop new methods on interpretation of geophysical data in terms of geological parameters with special emphasis on quantitative methods.

Extensive projects in aerogeophysics, begun in 1967-68, became operational during the report period and should show evidence of important production next year. The Skyvan and Queen Air projects mentioned in last year's report are proving most successful. Sufficient development data were obtained during the year so that technical recommendations could be made to the Mines Ministers Conference in September 1969, regarding airborne EM surveys.

The Federal-Provincial Aeromagnetic Survey Program continued, but as the work is now reaching into the climatically difficult far-northern areas, a new basis for contracting has been devised. New contracts will be for six years, they will be done by a consortium of companies and the government will take a greater share of the weather risk.

During the year 579 aeromagnetic maps were published; the total available now exceeds 5,000.

About 13,000 line-miles of high-resolution aeromagnetic survey data were obtained from low-level traverses made in cooperation with the National Aeronautical Establishment across the Atlantic Ocean between Gander, Newfoundland, Shannon, Ireland, and southern Greenland. This information is useful in determining ocean-floor spreading in the North Atlantic Ocean.

Studies directed towards the development and assessment of techniques for the remote measurement and delineation of rocks and minerals, properties and structures from airborne and borehole data were continued. Such techniques are likely to become increasingly important in the next decade.

Paleomagnetic studies, long considered to be rather esoteric, are beginning to indicate practical value; the work done in collaboration with International Nickel Company of Canada is a case in point.

GEOCHEMISTRY, MINERALOGY AND ECONOMIC GEOLOGY

Those aspects of geology that contribute most directly to our knowledge of the occurrence of economically important elements and minerals are the responsibility of this Division, whose staff also provides data and concepts that will contribute to the search for mineral deposits and develops methods that may be used in prospecting.

The major research projects conducted in 1968-69 were (1) the coordinated study of the geology of mineral deposits by a group of economic geologists, each of whom is responsible for research into the geology of economic elements; (2) the development and testing of geochemical prospecting methods; (3) mineralogical studies of ore- and rock-forming minerals; and (4) the long-term implementation of a geochemical census of economic elements in the crustal rocks of Canada.

Studies continued of the geochemical factors which control the concentration of nickel in basic and ultrabasic rocks, and a metallogenic map showing the various types of nickel deposits, their distribution and general geological environment, was submitted for publication. A fourteen-month study of Michipicoten iron-formations by a research associate from Japan was completed, resulting in new criteria for recognizing primary and metamorphic features in siderite-sulphide stratiform deposits. Studies of Canadian copper deposits, lithophile metal (Li, Be, Sn, W, Mo) deposits, titanium, vanadium and rare-earth deposits and lead-zinc deposits were continued and several progress reports were published. A major report on Huronian rocks and uraniferous conglomerates was prepared and publication was expected in May 1969.

Projects in geochemistry described in last year's report were continued. More than 100 visitors from industry consulted with members of the Geochemistry

Section. Many of these were particularly interested in the Survey's studies on radon as a method for uranium exploration and in the methods being developed for computer interpretation of geochemical data. Biogeochemical techniques were tested successfully in the Cobalt, Ontario district, and other studies in this field were continued.

Chemical and instrumental analyses were continued to provide compositional data on geological material. A total of 119,002 analyses were made on 25,400 samples in the laboratories of the Geochemical Section and 57,760 analyses were performed in the laboratories of the Analytical Chemistry Section.

Mineralogical studies made by the division include the physical and chemical properties of minerals and the geological significance of mineral associations and textures, use of X-ray diffraction, X-ray emission and absorption, and electron-beam techniques. The Survey's mineralogists compile and publish data on Canadian minerals, examine mineral and rock specimens as a public service, prepare collections of minerals and rocks for sale and maintain the Systematic Reference Series of the National Mineral Collection. In 1968-69, 8,628 sets of rocks and minerals were sold.

Work in geomathematics and data processing continued. An interesting aspect of this work is the development of mathematical methods for predicting the areal distribution of gold occurrences in greenstone belts and their relationships to the geological environment.

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY

This Division of the Survey is in Calgary and is responsible, through field and laboratory research, for describing the geology of the western and northern sedimentary basins from the international boundary to and including the Arctic Islands and between the Canadian Shield and the Rocky Mountain Trench. The Institute also has custody of samples and other data resulting from exploration in all provinces of western Canada and is also the repository of drilling cores and other data which are submitted in conformity to regulations. The scientific work is carried out by six research sections. During the report period the Institute comprised 40 scientific and professional staff, 22 technical staff and 18 administrative support staff. Liaison is maintained with members of the petroleum industry, universities, provincial departments and professional societies. During the year more than 2,000 persons used the core and sample examination facilities. The number of samples now exceeds eight million, and there are 8,000 boxes of core.

Field work was carried out by parties of the Arctic Islands Section in southeastern Ellesmere and eastern Devon islands and in the Foxe Basin area. The Structural Geology Section is responsible for the geometric analysis of formations that may contain fossil fuels or saline substances and for basic research into the mechanics of deformation. In support of these objectives five staff members undertook field investigations. The Paleozoic and Mesozoic Stratigraphic Sections are responsible for basic research towards establishing a stratigraphic and historical framework for the strata of these periods. "Operation Norman", a two-year, aircraft-support reconnaissance project in northern District of Mackenzie, involved members of both sections and resulted in the mapping of 100,000 square miles. The western Paleontology Section carries out studies designed to date the sedimentary rocks of western and northern Canada and to provide descriptions of fauna and flora vital to stratigraphic correlation. A total of 2,420 lots of fossils were examined and 98 reports were prepared. In addition, 17 reports on 676 lots were prepared by university paleontologists for use by the Survey. Mention was made in the 1967-68 Annual Report of discussions held between industry and the Petroleum Geology Section. As a result, four projects were initiated this year: (1) studies on the environment of oil and gas in western Canada; (2) a collaborative project with the Coal Research Section (Ottawa) to study the metamorphic changes in coals as an indication of hydrocarbon types; (3) a geochemical study in cooperation with Panarctic Oil to investigate trace amounts of hydrocarbons; and (4) a joint program with Geoservices North America Limited to test their surface-prospecting method.

QUATERNARY RESEARCH AND GEOMORPHOLOGY

This Division provides geological and geomorphic knowledge about unconsolidated deposits and landscape features and assists in applying this knowledge to the Canadian economy. This mission has a most important economic aspect involving the application of geological and geomorphic knowledge in mineral exploration, agriculture, forestry, water supply, pollution and waste disposal, construction and foundation engineer-

ing, and in urban, rural and recreation planning. At the end of the fiscal year the staff comprised 34 professionals, 16 technicians and four administrative employees. Twenty-six of the professional staff engaged in field work in 1968. Seven staff members are in Calgary and one at the Canada Centre for Inland Waters at Burlington.

The Regional and Stratigraphic Projects Section describes and explains the Quaternary geology and geomorphology of Canada. Field work was carried out in eight provinces and the Northwest Territories. Reconnaissance studies in southeastern Ellesmere Island and northeastern Baffin Island were completed, and several staff members continued a variety of studies on Banks Island. Studies of the glacial geology of southwestern New Brunswick continued. At the request of the provincial government the feasibility of prospecting for sand, gravel and silica sand near Moncton was studied.

The Sedimentology and Geomorphic Processes Section investigates processes of landscape change involving slope movement and erosion, frost action, weathering, and sediment movement and accumulation. During the report period studies were carried out on a variety of topics including varved sediments, eskers in Keewatin District, raised beaches in the southern Lake Huron region, and the delta lakes of Mackenzie Delta.

The Paleoecology and Geochronology Unit provides radiocarbon dates and analyses of fossil materials (mainly pollen). Such studies are valuable in investigating changes in environment and plant and animal distribution during the Quaternary. During the year, 186 radiocarbon age determinations were made; 14 were on archeological material submitted by the National Museums of Canada.

Studies by the Engineering and Indicator Geology Unit are of direct practical value. During the year the Survey provided advice to the Inland Waters Branch on proposed power sites and river-diversion projects on the Albany River, Ontario, and to the St. Lawrence Seaway Authority during construction of the new Welland Canal.

Mines Branch

The Mines Branch is a complex of laboratories and pilot plants designed to assist the Canadian mineral industry in the more efficient extraction and elaboration of mineral wealth of all types, and to improve and broaden the uses of metals and minerals. During the twelve months under review the Branch continued a number of promising research projects and started several new ones.

The work is carried on in six Divisions—Physical Metallurgy, Fuels Research Centre, Mining Research Centre, Mineral Sciences, Extraction Metallurgy, and Mineral Processing.

Physical metallurgy is concerned with the composition and behaviour of pure and alloyed metals as well as the smelting of iron and steel. Much of the work falls into the category of "troubleshooting" for government departments and private industry. Fundamental research into the melting and solidification of metals and the physics of liquid metals also forms part of the Division's work. Research on fuels concerns especially the treatment of Canadian coals to render them more acceptable to the metallurgical industry at home and abroad, the chemical structure of hydrocarbons, and the beneficiation of Canadian heavy crude oils. The Fuels Research Centre also seeks to improve the safety of mining equipment in explosive atmospheres and to reduce air pollution from combustion.

Mining Research Centre specialists concentrate on such problems as rock breakage, ground and dust control, managerial operations control, and the distribution of technical information to the mining industry. In the Mineral Sciences Division the emphasis is on the composition and properties of useful minerals. The complicated sulphides occupy much attention, as do multioxide systems of such elements as niobium, tantalum, and aluminum. Research is also being conducted on the fabrication of piezoelectric and magnetic ceramics, surface phenomena on minerals, and crystal structure. In the Extraction Metallurgy Division, bacterial leaching of uranium ore, an experimental shaft-and-electric-arc furnace, prevention of embrittlement during electroplating, and the thermodynamics of metallurgical reactions are the main fields of interest. Research in mineral processing covers practical aid in the processing of newly discovered ores, the evaluation of commercial ceramics, the improvement of industrial minerals such

as shales and concrete, and the flotability of non-metallic minerals.

Details of these and other investigations will be found in the following.

PHYSICAL METALLURGY DIVISION

The Physical Metallurgy Division undertakes a wide variety of work concerned with research, development, processing and fabrication, and application of metals and their alloys. This work is undertaken in support of the Canadian mining and metallurgical industry and also in response to requests received from other government departments.

The research and development of the Division have been organized under five headings: casting and solidification, forming and fabrication, engineering properties and service evaluation, alloy metallurgy, and research-and-development techniques and equipment. There are a number of active projects in each of these areas. Some typical examples of these projects are presented.

In the field of casting and solidification, work is being carried out to evaluate the influence of various deoxidation methods on certain critical properties of structural steels. A project is under way on the development of grain refinement for cast bronzes. Fibre-reinforced composite materials produced by directional solidification are being evaluated in another research project.

Forming-and-fabrication projects include research on the problem of low ductility in welds of 18% Ni 250 maraging steel. This research has established optimum welding and heat-treating conditions to prevent brittleness in such welds. Another forming-and-fabrication project is a study of the relationship between sintering behaviour and powder-particle characteristics of Canadian nickel powder. Research on the hot and cold rolling of wrought nickel is another example of work in this area. This project was undertaken to develop design data for the proposed new rolling mills for the production of strip for nickel coinage at the Royal Canadian Mint.

A great deal of the work in engineering properties and service evaluation has been concerned with mechanisms of failure by fracture, fatigue and hydrogen embrittlement. One project is concerned with the fracture mechanisms of ultra-high-strength steel. Another project has indicated that atmospheric environment can play a critical role in the fatigue behaviour of high-strength aluminum alloys. This emphasizes the need for a better understanding of the role of the surface oxide on this and other commercial aluminum alloys. Research has been undertaken to determine the degree of hydrogen embrittlement that might result from the fabrication of heavy-structural-steel sections by welding followed by pickling and galvanizing. This work was undertaken to help evaluate the maintenance cost of galvanizing heavy section-welded steel structures, such as bridges, etc.

In the field of alloy metallurgy, research is continuing on the development of high-strength cast steels of improved toughness. Several research projects concern the relationship between the alloy metallurgy of a wide range of alloys and their mechanical properties and corrosion resistance. These projects cover steels, aluminum, magnesium, copper, titanium, uranium, zirconium and zinc alloys.

A considerable amount of work has been expended on the development of new research techniques and associated equipment. Work on the electrochemical determination of soluble oxygen in molten steel is continuing in association with a commercial organization. A complete system for use in steel plants for the electrochemical determination of soluble oxygen in molten steel has been designed and made ready for industrial trials.

In addition to the above research and development the Division has responded to requests for research assistance from government departments, companies and universities. This Division handles several hundred such requests each year. A few typical examples are outlined.

Among the more intensive investigations was the study of pipeline failures. During the course of this year at least seven pipeline failures were investigated on behalf of the National Energy Board. In all cases metallurgical reasons for these failures were identified, thereby permitting the necessary corrective measures to be taken.

An evaluation of three different welding processes used to seal clad atomic-energy fuel-rod elements was undertaken for Atomic Energy of Canada Ltd. This investigation indicated that only one of these proposed methods was suitable.

Two investigations were undertaken on behalf of the pulp and paper industry. The brittle failure of abrasion-resistant white-cast-iron wear blades in ground-wood refiners was investigated. Recommenda-

tions were made that would improve the service life of this item. The second item was a component of a quality-control installation used in the production of ground wood pulp. A critical component of this installation was failing with very short life. The causes for failure were identified and recommendations for the correction of this difficulty were made. These recommendations have subsequently been successfully adopted.

The Department of Transport requested advice on the repair of bottom plates on ships of riveted construction that were built during the period 1900-1930. Based on our examination of samples it was recommended that repairs should also be made by riveting. Precautions were also given concerning the susceptibility of this kind of steel to low-temperature brittle fracture. A Quebec shipyard was advised about methods of welding vertical steel plates.

The Royal Canadian Mint requested an investigation to determine any differences in physical properties and microstructure of 1968 twenty-five-cent coins made from nickel from two different sources. It was demonstrated that there were significant differences in certain physical properties of these coins that would make possible the identification of source material.

Technical assistance was given to many Canadian universities, usually by preparing for them small quantities of special alloys for post-graduate research.

As usual the Division has been heavily involved in the certification of industrial radiographers across Canada. During this period 12 persons completed practical tests in Ottawa. A total of 30 senior and 82 junior applicants were certified. The certification of radiographers in the category of aircraft structures has been established. The practical tests are conducted at the Canadian Forces Base in Trenton, Ontario, under the guidance of this Department. The Department of Transport has ruled that radiographic inspection of civil aircraft must be supervised by certified personnel. It is expected that this ruling will result in an increase in the number of applicants seeking certification.

During the past year, three outside organizations have made use of the research facilities of this Division. The Steel Castings Institute of Canada has a permanent staff of two at the Division to conduct research on its behalf. The Canadian Zinc and Lead Research Committee maintains one research worker here. The Department of National Defence has been supplying one man intermittently to carry out corrosion research.

FUELS RESEARCH CENTRE

World conditions are continuing to exert a profound influence on Canada's mineral-fuel economy. This fact is strongly reflected in the activities of the Fuels Research Centre, which has as one of its prime objectives the development of processes for the conversion of Canada's mineral fuel resources into products that will meet the diverse needs of modern industry both at home and abroad.

The resurgence of Japan from postwar privation and chaos to its present position as the second-largest industrial power in the free world, in terms of gross national product, has been associated with a rapid expansion of the Japanese steel industry and a greatly increased demand for coking coal. Part of this demand is being met by the establishment of fifteen-year contracts for western Canadian coking coal. The value represented by the contracts signed to date amounts to $1.5 billion, and this market appears to be growing steadily.

To ensure the expansion of the Japanese market (and the development of new markets in the central part of North America) the Fuels Research Centre has improved and modernized its facilities for evaluating coking coal. This is essential to satisfy the growing demand for assessment of the quality of reconnaissance samples of coal from western Canada. The Centre has also improved its processing capability on the pilot scale to remove the mineral matter from coking coal. This has been allied with the development of new methods of drying fine coal. These new techniques show promise of reducing costs, as well as the atmospheric pollution associated with thermal driers. These efforts to bring to fruition technical innovations as quickly as possible are essential to meet the requirements of the Japanese market.

In anticipation of the problems arising from the transportation and storage of fine coking coal, research was initiated to develop new and more sensitive analytical techniques to detect and measure the weathering of coal. This investigation was successfully concluded during the year with the development of a new chromatographic technique for the detection of weathering and an interesting new method for the measurement of the total organically combined oxygen in coal.

The construction of the new buildings for the Fuels Research Centre on the western outskirts of Ottawa was largely complete at the end of December, when the relocation of the equipment and laboratories

began. One of the larger items to be constructed is the modern 18-inch oven, which will carbonize an 800-pound charge of coal. This facility is being built with the aid of funds from the Canadian Carbonization Research Association, which is an industrial group composed of Canada's major steel producers, coal companies and a coal-tar-processing company. This reflects the close association between the Metallurgical Fuel Engineering Group and the metallurgical industry to find new techniques for matching Canada's coal resources to the special requirements of this industry.

Good progress has been made by the Western Regional Laboratory of the Fuels Research Centre in Edmonton on the application of compound water cyclones to the upgrading of Cape Breton coals. This work was conducted with the encouragement of the Cape Breton Development Corporation and the support of the Dominion Coal Board. At the year-end, these studies had been extended to the problem of reducing the pyrite content and mineral matter of fine coal.

The Hydrocarbons Group of the Fuels Research Centre is concerned with the evaluation of Canadian petroleum resources (including engineering studies of transportation and comparisons of Canadian fossil fuels); gaining a better understanding of the fundamental chemical structure of these raw materials; and, finally, developing improved processes to beneficiate Canada's heavy crude oils to supply the needs of the future.

The number of Canadian crude oils evaluated during the year was reduced due to staff shortages and the need to accelerate pilot-plant work, as it was known that the relocation of this equipment to the Corkstown Road site would inactivate these programs for a considerable period.

The emphasis in applied petroleum research has continued to be on the development of processes and equipment for the conversion of valuable products. Part of this program involved an appraisal of the combined liquid-and-vapour-phase hydrogenation process. The pilot plant, using a circulating suspended catalyst, was operated for 700 hours. Many of the mechanical difficulties were overcome to achieve smooth operation. The results have not been fully assessed, but the indications are that when residual oil is used as the feed-stock, the throughput is low and the product quality exceeds specifications.

The group also evaluated thermal hydrogenation of whole crude from the Athabasca tar sands to yield a refinery feed-stock. It was demonstrated that hydrogenation at moderate pressure, without catalyst, offers considerable promise as a practical initial treatment. This simple, partial refining step allows the residuum to be reduced to levels that are in balance with the energy requirements of operating a hot-water-separating plant and the demands of mining.

Research in catalysis, associated with petroleum refining, has led to the development of an inexpensive process for making high-surface-area alumina for catalyst supports. This alumina is capable of being formed into pellets of high mechanical strength with relatively low pelleting pressures. These pellets have a greater capacity for bringing about reaction, due to their low density and the relatively greater accessibility of the internal surface.

The Fuels Research Centre is concerned with research that will improve the safety of mining in Canada. In this connection, an important contribution was made by the Canadian Explosive Atmospheres Laboratory through the certification service and by conducting research on the explosive properties of gaseous mixtures, particularly as they influence the design of electrical equipment used in mines. Investigations were made of the strains that develop on the walls of explosion-proof electrical equipment when subjected to various internal gas/air explosions. The ability of an enclosure to resist structural damage from internal gaseous explosion depends not only on the magnitude of the stress, but also on the natural vibration-frequency period of the enclosure. This information will help Canadian industry to design more effective equipment, and will also provide a basis for examining imported mining machinery.

Air pollution from combustion sources is a matter of increasing public concern. Research to alleviate some of this pollution is being conducted at the Canadian Combustion Research Laboratory. The development of a new and more accurate plume-rise equation to predict the manner in which stack gases are dispersed from tall chimneys has been completed, and preparations are in progress for field studies to secure more detailed information on the settling of particulates, as well as the variations in concentrations of sulphur dioxide with distance from the stack. Research is also in progress on domestic-size blue-flame burners in an attempt to reduce smoke and pollution from unburned hydrocarbons. As the formation of noxious atmospheric pollutants is influenced by the aerodynam-

ic conditions existing in the furnace, a tunnel furnace is now under construction to study the aerodynamics of flames. This furnace, when completed, will provide a flexible facility enabling this laboratory to complement the work of the International Flame Research Foundation at Ijmuiden, Holland.

MINING RESEARCH CENTRE

The Mining Research Centre carries out research in three laboratories: Canadian Explosives Research Laboratory, Rock Mechanics Laboratory, and Elliot Lake Laboratory. In addition, many of the individual projects are done in mines throughout the country with the joint support of the companies and the Centre.

The Centre operates on the project system, individual projects being integrated with the work of individual companies and universities throughout the country. Wherever possible, the prospect of an attractive payoff is used in the selection of projects. Those projects on which the potential benefit-cost ratio is particularly high receive maximum concentration of the budgetary resources.

The *breaking of rock* both at the mining face and subsequently in reducing the large blocks of ore to a fine size suitable for processing is a major part of mining. The objective of rock-breakage research is to explore the mechanics of breakage using forms of energy other than explosives with a view to radically new mining methods. This is a pioneering activity undertaken at the request of the Mining Association of Canada as a result of a survey showing that their members believe rock breakage is one of the most important areas in which research should be able to effect savings. Beside helping to improve efficiencies in current systems through the discovery of novel methods of drilling, blasting, crushing and grinding, it was also envisaged that conventional operations may be telescoped into some combined procedure quite unlike current practices. The work is being done primarily in the Elliot Lake Laboratory.

Blasting research is also being pursued to increase safety and to reduce the cost of drilling and blasting in industry, which accounts for the expenditure of approximately $100,000 per year in Canada. By the application of analytical techniques it should be possible to produce significant savings within a reasonable period of time. The resources of the Canadian Explosives Research Laboratory, the Rock Mechanics Laboratory and the Elliot Lake Laboratory, together with those of some private companies, are all being used for this work.

How to ensure stability of the rock around a mining excavation—that is, *ground control*—is an important aspect of mining. Solutions of the problem are being sought through analytical methods, which have been used in the design of building structures for over a hundred years. Before such methods can be successfully applied, however, considerable research is necessary, both because of the great variety and complexity of mining openings in Canada and because adoption of the large safety factors common in structural design might seriously impair effective extraction. The work is done mainly through the Elliot Lake Laboratory.

Besides the basic projects that are being pursued with the resources of the Mines Branch alone, cooperative projects with mining companies from Newfoundland to British Columbia constitute a major part of the ground-control research. Control of the weak and friable roof rocks in both the eastern and western coal fields is being studied with various companies. Work is being done in the Saskatchewan potash mines and Ontario salt mines. In the former case, little experience exists in the world for mining such materials at the depths of these deposits. Studies also are being conducted to establish appropriate designs and operating sequences for mining multiple, parallel seams in one of the uranium mines. Stress and deformation measurements have been made in hard-rock mines subjected to rockbursts. Much information has been gathered from underground measurements in base-metal mines in both Quebec and Ontario on the stability of pillars. Design procedures have been evolved for support with rock bolts; work is proceeding to achieve the same objective for support supplied by filling with waste mill tailings. Canada has one of the largest underground mining industries in the world, and such studies are extremely important to the Canadian economy.

As over 50 per cent of the ore produced in Canada comes from open pits, a substantial part of the research budget of the Centre is applied to open-pit mining. To produce 100,000 tons of ore from these mines, typically 150,000 tons of waste rock must also be excavated from the slopes required for these pits, which can be as deep as 1,000 feet. The economic feasibility of any potential open pit is, therefore, largely dependent on the slope to which the walls must be cut. Scientifically determined *optimum pit slopes* would be worth much to industry. Individual mines however, do

not have adequate incentive to engage in the comprehensive program required for such a technological advance, and government enterprise is required.

Computer simulation of open-pit slopes is being used to examine the basic factors influencing the stability of slopes in rock. Under study are stress distributions in typical slopes subjected to varying tectonic stresses together with deformation patterns and their correlation with known modes of failure. In addition, optimization of excavations is being sought by changing slope angles as the mine gets deeper.

Research is being conducted towards improving the *environmental conditions* in mining. Whereas the physiological effects are the concern of other research groups and ventilation design is done by mine staffs, the physics of measuring environmental conditions requires the more detailed study that is being undertaken in this program. At the present time, the projects concern primarily standard methods for measuring dust and radiation hazards and are being conducted in close cooperation with the Mine Accident Prevention Associations of Ontario and Quebec as well as with individual companies experiencing critical problems. Although conditions in Canadian mines are generally good, improvements must be made constantly in the working environment (e.g., air-conditioning, humidity control, noise suppression, and good lighting) to ensure continuous interest on the part of technical personnel and labour in working in the mines. The work is being done primarily in the Elliot Lake Laboratory.

Work has been started on *systems analyses* of various mining operations. Advances that are made by physical research on the various phases of operations (drilling and blasting, ground control, transportation, etc.) are being examined to determine their influences on mine economics. Computer programs are to be developed for use by company staffs on mining properties.

With the high degree of complexity of current technology, we find that no organizations exist in the country with the personnel and facilities capable of assisting those with problems in many specialized areas. Consequently, calibration, testing and advisory services are provided when required by companies and agencies in the mineral and associated industries. This is consistent with the Mines Branch policy of orienting its research to fill gaps in technology of particular concern to the country. At present, most of the work is being performed at the Canadian Explosives Research Laboratory.

The general function of *communication* is being expanded by the development of an Information Centre involving both the Mines Branch Library and the Elliot Lake Laboratory whereby, through information officers and telex links, it is planned to provide industry and the universities with assistance in finding and obtaining the latest research information on any subject. At present, integration with private research is achieved either through joint projects or through liaison on subjects of mutual concern. The companies cooperating with the Mines Branch in research produce approximately 75 per cent of the Canadian mining output. Besides the conventional method of publishing significant results in journals, interim reports are written. Some of these are distributed exclusively through the Mining Association of Canada to interested companies, while others are used as research notes that are exchanged with laboratories both in Canada and abroad.

In 1963, the Canadian Advisory Committee on Rock Mechanics was formed to stimulate greater interest in this base science for mining and to coordinate research. The membership has consisted primarily of representatives of industry and of the universities, with Mines Branch personnel essentially providing the secretariat (the chairman and the secretary).

One of the principal ways in which the Mines Branch, with advice from the committee, has been able to stimulate research is through its grants in aid which, starting with $10,000 in 1962, have grown to a total of $310,000 for mining research in general with the majority of these funds being used for research in rock mechanics. The committee also periodically examines and appraises the research of the Centre in rock mechanics.

MINERAL SCIENCES

The Mineral Sciences Division is a multi-disciplinary "Materials Research" type of organization concerned with research of use in the whole field of minerals technology. The Division divides its activities into three main fields: (a) mission-oriented research into the properties and behaviour of minerals and related materials, (b) studies of the characteristics of mineral assemblages and the distribution of the values that bear on the exploitation of ore deposits, and (c) inorganic chemistry (phase-equilibrium studies of oxide systems, structural chemistry) and analytical research with a special interest in the development of internationally accepted standards of analyses.

Sulphide Research

The properties of sulphides and related minerals are being investigated in considerable depth to suggest new and improved methods of beneficiating and using this important category of ore minerals. Insight into the forces that bind atoms together to form stable mineral structures has been gained through infrared spectroscopy of a number of sulphides, including pyrite (FeS_2), marcasite (FeS_2), cattierite (CoS_2), vaesite (NiS_2), cobaltite (CoAsS), arsenopyrite (FeAsS), gudmundite (FeSbS) and loellingite ($FeAs_2$). Physical-chemical factors that affect the structural stabilities and compositions of the skutterudite minerals $(Co, Ni, Fe)As_3$ have been deduced from a critical analysis of their compositions, solid-solution limits, magnetic properties and specific gravities. Investigation of complex intergrowths of silver-antimony-mercury minerals by microscopy, electron-probe microanalysis and phase-equilibrium studies have, for the first time, provided an adequate characterization of, and explanations for, ore assemblages in the Cobalt mining camp. Some progress was made toward characterizing a new copper-iron sulphide mineral in terms of its stability relations and crystal structure. Improvements were made in level of precision. Single crystals of a number of sulphides required for experimental work in the sulphide research have been grown successfully by vapour-transport and Czochralski methods. To ascertain the surface properties of sulphides a kinetic study was initiated of surface-solution equilibria of lead sulphide in aqueous media. These and other research projects on sulphide minerals have substantially extended the knowledge about their fundamental properties and behaviour.

Mineral-Surface Studies

Research continued of the mineral-solution interface. A phenomenon known as the double layer occurs at the surface of minerals in contact with ionic solutions, with electrochemical properties that can be measured. This has been done for a number of oxides—hematite, silica and others—and the work has now been extended to sulphide minerals. These measurements have proved more difficult because of greatly increased surface reactivity. Using the data obtained, together with theoretical relationships, it has been possible to derive thermodynamic parameters useful in predicting the characteristics of adsorption—important to most mineral-treatment processes, including flotation. Other studies related to surface phenomena undertaken during the year, were electrophoretic measurements of mineral-leaching bacteria in direct-current fields; oleic-acid adsorption on hematite; and preliminary work on surface properties that are of interest in electrostatic separation.

Ferrites

An expanding program on the chemistry and technology of magnetic ceramic materials based on ferrite compositions is under way. The work has hitherto been restricted to studies of "hard" or permanent-magnet ferrites, which are widely used in computers and magnetic tapes. Studies of the effects of such variables as stoichiometry, particle size and shape, calcination and sintering times and temperatures on the magnetic properties of the ferrite ceramics have been conducted, and a study was made of the kinetic mechanism of their formation. As a consequence of the knowledge and capabilities that have been established at the Mines Branch in this work a number of Canadian companies have been directly assisted and advised.

Mineralogical Studies of Canadian Ores

Studies of ore-mineral assemblages that are characteristic of Canada's economically important deposits have been undertaken to provide basic mineralogical data of value in the exploitation and beneficiation of the ores. Other aspects of the depositional history have been gleaned from a detailed study of the textures of the other ore minerals. A lengthy study of the Cobalt-Gowganda area is nearly completed, on the basis of which mineralogical and chemical zoning has been delineated in the ore deposits, textural and compositional relationships of the constituent minerals have been clarified and described, a number of minerals in the deposits have been fully characterized, and a large body of new knowledge on the silver mineralization has been accumulated.

Non-destructive Assaying of Metal Values in Ore Estimation and Grade Control

In recognition of the need to obtain large volumes of data for use in ore estimation and grade control, studies were undertaken to evaluate the technique of using portable X-ray fluorescence equipment. Field and laboratory work indicated some range of applicability, but the limitation of X-ray fluorescence to only the surface of minerals proved to be an obstacle in some cases. As a result, feasibility studies of using neutron

activation, which has substantial penetration into the material being analyzed, were carried out and the results showed promise. The greatest attention was focussed on copper. Accurate and rapid analyses can be made, but the technique of applying such a method in the field for assaying drill cores and samples must still be developed.

The Analysis of Ores and Minerals. A wide range of analytical techniques, conventional chemical, spectroscopic and instrumental, continues to be employed in the solution of problems of composition arising in researches throughout the Mines Branch, as well as from industry and other government organizations. For instance, significant advances were made in the limits at which gold can be determined in its ores. By combining neutron-activation analysis with the fire-assay method, greater sensitivity was achieved, and custom assays of samples for platinum-group metals were performed for a number of private companies or individuals. This service was instituted in 1967 because of difficulties encountered in obtaining consistent results by outside laboratories in the determination of these elements.

Instrumental Analyses

The following instrumental types of techniques have been used in connection with problems under investigation in the Division: spectrochemical analysis in the visual, infrared and X-ray spectral regions, both qualitatively and quantitatively; atomic absorption spectroscopy, which has replaced conventional chemical analysis in the determination of many metallic elements, with a consequent saving of time and improvement of accuracy; differential thermal and thermogravimetric analyses, which serve a very useful purpose in following the course of complex mineralogical and metallurgical reactions; neutron-activation analysis, which affords a very useful direct method of estimating oxygen in metals; and phase-equilibrium studies, which give information concerning the temperature and compositional stability of the compounds occurring in multi-component oxide and other systems.

Crystal-Structure Analysis. A very comprehensive and sophisticated system has been assembled and set in operation for the detailed study of atom positions in crystals of interest to the Division. This facility, incorporating among other items a four-circle goniometer and a computer for data collection and equipment control, is unique in Canada and has been used for the study of a number of compounds.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, applied research continued on hydrometallurgical and pyrometallurgical processes, on electroplating technology and on causes and prevention of metal corrosion. The work was broadly based to meet the immediate and future needs of Canadian industry, and new developments were communicated to the industry through publication in technical journals, and through cooperative industry—Mines Branch organizations such as the Canadian Mineral Processors and the Canadian Uranium Producers Metallurgical Committee, and by field trips, informal contacts, and direct reports.

Hydrometallurgy

Bacterial action on iron sulphides under favourable conditions can produce oxidizing acidic solutions which have considerable economic potential in the leaching of certain ore minerals. A long-term research program has been directed toward developing a plant process embodying bacterial action on iron-sulphide-bearing uranium ores. Moderate acidity, agitation and slurry density have been found necessary for a viable bacterial environment, and in a pilot plant designed to test results of the research program, these conditions were attained by use of thickeners as bacterial leach reactors. While extraction efficiency is as yet slightly lower than in conventional leaching, the pilot-plant study has shown that under favourable conditions an economic process could be developed, since heat and reagent costs are considerably reduced.

In conventional leaching of uranium from Elliot Lake ores, there is some extraction of rare earths, thorium and yttrium. While only the yttrium is currently of economic interest, the rare earths and thorium have a market value if available in a relatively pure state. An investigation using solvent extraction was therefore undertaken to develop methods of producing separate rare earths.

A systematic re-evaluation of uranium-leaching variables has been carried out over the past several years by mathematical models derived from statistically-designed experiments. The models delineate the significant leach variables and their optimum ranges, and can be used to predict the effects of changes in these variables. The work was related to process developments in the operating uranium-leach plants and showed that process temperatures, which have gradual-

ly been increased over the past decade, are approaching the limits of optimum economy.

Pyrometallurgy

A combination shaft furnace - electric furnace has been under development for some time at the Mines Branch to provide a more efficient electric smelting unit that can be built to suit the requirements of a broad range of Canadian metallurgical operations. The unit utilizes energy sources of electricity, gas and oil, each in its most efficient and effective way, to obtain maximum productivity from the electric furnace.

As it is now developed, substantial economies in electrical energy are achieved by pretreating incoming feed with hot reducing gases from the electric furnace and from gas burners, in the shaft furnace. The experimental program of the past year was directed largely toward determining the operational benefits of the improved unit, and for this purpose smelting programs were carried out producing pig iron from iron-oxide pellets, and steel from SL-RN pre-reduced pellets. In the smelting of iron oxide it was found that 25 per cent of the reduction of the feed had been achieved in the shaft furnace by the hot reducing gases. More sophisticated data-gathering equipment was installed and data-processing facilities have since been improved by installation of a terminal linked to a National Research Council computer, to enable operating data to be analyzed rapidly enough to guide the control of furnace conditions.

Corrosion and Its Prevention

Research on the causes and prevention of metal corrosion in industrial environments was carried on throughout the year, both in the laboratory and in the field. Corrosion of reactive metal surfaces by sulphurous acid deposited from atmospheres contaminated by sulphur-dioxide-bearing combustion gases can be severe in industrial areas, and research was continued toward prevention of such attack. Reagents such as sodium oxalate and hexamine were earlier found to inhibit sulphurous acid corrosion of mild steel and zinc, and in the past year studies on aluminum showed that borax was partially effective for the protection of this metal.

In the long-term program on the improvement of industrial electroplating, a new plating-bath composition for electroplating chromium on high-strength steel was developed. The chromium coating applied to the high-strength steel is non-porous and thus provides greatly improved protection. It was found, too, that mild steel could be given a non-porous chromium coating from the new plating bath, so that the new development could have wide industrial application.

In the field a survey of the effects and possible causes of corrosion in the mining industry was undertaken, and conditions underground and on surface were studied. The results of the survey are being used to formulate research to combat the corrosion difficulties of the mining industry.

Basic Research

The basic research of the Division was largely concerned with the kinetics and thermodynamics of metallurgical reactions of importance to the mining industry. Typical of the work carried out is the long-term research on the kinetics of leaching chalcopyrite ore. This study is directed to developing the underlying principles and controlling factors governing the extraction of metals such as uranium and copper from ores, and is of importance in treating low-grade ores.

The sulphur in many Canadian metal-sulphide ores can be turned into a valuable by-product if it can be recovered economically and sulphur-dioxide release to the atmosphere avoided. A possible route to achieve these aims is the chlorination process, which produces elemental sulphur and metal chloride, and a long-term program has been under way to define underlying principles and basic data necessary for process development.

MINERAL PROCESSING

The Mineral Processing Division carried out basic and applied research in aid of the mining, ceramics and construction-materials industries and continued to supply expert advice to industry and other government departments.

Research to improve basic processes for concentration of metal ores in the mining industry included studies of grinding-process control, development of new types of filter media, investigation of the electrochemical properties of surfaces of minerals in aqueous solution, systematic evaluation of the variables of hydrocyclone classification, and flotation of iron, copper and molybdenum ores.

Applied research was conducted to assist the mining and metallurgy industries in development of new mines, improvement in existing plants, and better utili-

zation of resources. Treatment processes were developed for new mine projects including copper-nickel, lead-zinc, copper, silver, gold and iron ores. Industrial assistance projects included reclamation of chromite foundry sand, use of plant tailings as mine backfill, recovery of silver from old tailings deposits, and participation in the preparation of international analytical standards for platinum.

A pilot plant was operated to further develop an economical process for the treatment of a complex base-metal ore from New Brunswick.

Research in the industrial-minerals field was directed towards new and improved processes for the conversion of Canadian industrial minerals to useful products. The separation of non-metallic minerals, high-temperature preparation of ceramic products, and the improved utilization of mineral products were some important areas of research and investigation. Technical information was provided on processing methods, and on specifications of a wide variety of minerals and products. Evaluations were carried out on numerous samples of industrial minerals which were submitted by industry, the public, and other government agencies.

Long-term projects continued in the non-metallic mill dealing with the floatability of industrial minerals, removal of reagent coatings from mineral particles, the development of mineral-processing equipment and the recovery of weakly magnetic minerals. Investigations on the beneficiation of industrial-mineral ores included fluorite-barite from Nova Scotia, quartz sand from Ontario, spodumene from Manitoba, barite from Ontario, scheelite from the Northwest Territories, ultrabasic rock from Ontario, and marl from Saskatchewan.

Experiments on the thermal properties of ceramic products, rocks and minerals indicate that a method has been developed by which the thermal conductivity of rocks composed of several minerals can be calculated. Assistance was given to a Canadian company by providing it with technical procedures developed at the Mines Branch on the manufacture of piezoelectric ceramics. Laboratory investigations were initiated to determine how Canadian-manufactured aluminas could be used in the manufacture of electronic ceramics, and how a combination of Canadian alumina and kyanite could be used for the manufacture of special ceramics. Research and development continued on Canadian clays and on clay products, particularly from Ontario, the Atlantic Provinces and the Prairies.

An extensive research-and-development project has resulted in an accelerated strength-testing method for early prediction of the 28-day and 91-day compressive strength of concrete. Field test data received from several companies indicated the value of the method, and several organizations are planning to use it. The CSA Committee on Concrete Materials and Methods of Concrete Construction decided to include the method as information in its Standard A-23. The work on the ring-test for determining the tensile strength of cement, mortar, gypsum plaster and concrete created widespread interest both nationally and internationally. Of all the methods available, the ring test appears to be the only practical one for determining the tensile strength of concrete that incorporates aggregates up to 3 inches maximum size. Investigations continued on the assessment of lightweight aggregate and concrete, and on the evaluation of building and ornamental stone. Of particular interest was the finding that gem-quality lapis lazuli from Baffin Island was suitable for the establishment of a small industry for the Eskimos in that area.

Initial studies of the autoclave calcination of a slurry of by-product synthetic gypsum from phosphoric-acid plants indicated that a quick-set, hemi-hydrate plaster could be produced by this technique. The static system for determining the length-diameter relationship of chrysotile asbestos fibre is being investigated further by the Quebec Asbestos Mining Association. The procedure for orienting chrysotile asbestos fibres was allowed by the U.S. Patent Office. The technique for determining surface area, based on a modified gas chromatograph was turned over to Canadian Patents and Development Limited for further study.

Almost all studies carried out in the Division require prior mineralogical evaluation. Investigations of the relationship between the mineralogy and ceramic properties of clays and shales and between the mineralogy and physical properties of aggregates and building stones are carried out continuously.

TECHNICAL SERVICES

The Technical Services Division provides engineering and technical support services to the six Mines Branch divisions engaged in fundamental and applied research. The Division provides consulting and design-engineering capability in the mechanical, electrical, industrial-instrumentation and control technologies.

The engineering group is backed up by skilled technicians and trades craftsmen who support research

personnel by developing, manufacturing and installing many classes of equipment for laboratory and pilot-plant applications. These craftsmen, who represent most of the building-construction and industrial trades, have developed a capability to work with a wide range of standard and exotic materials, metals and alloys and to fabricate devices from the same. Because of this diversity the Technical Services Division has successfully completed broad and complex projects as well as highly specialized ones.

Altogether the Division completed 2,703 work orders during 1968-69. Preponderant among these was work done for the Physical Metallurgy Division.

Further work on machineability and fatigue was carried out. Metal-cutting research was undertaken by a major Canadian steel company.

The Division collaborated with the non-ferrous section of Physical Metallurgy Division to provide a metrology service for its research on the ageing properties of various magnesium alloys. The metrology facilities of the Division are able to provide a direct service to the research scientist, as very precise length measurements can be made under environmentally controlled conditions. A long-term ageing project of this nature requires that the rate of change of temperature in the metrology room be held to a minimum. It is expected that improved environmental-control equipment will be purchased and installed this year.

Continuing development was carried out on the ion-bombardment equipment for the Physical Metallurgy Division. As a direct result of this work it was recognized that the use of hollow hemispherical collectors provided an excellent method of teaching the three-dimensional geometry associated with crystallographic problems. A device was developed in conjunction with the research group involved which makes possible the direct production and viewing of stereographic and gnomonic projections of any chosen crystal orientation. A patent has been applied for through Canadian Patents and Development Limited.

A three-year program of updating the Physical Metallurgy Division's sixteen heat-treating furnaces was completed.

LIBRARY

The Mines Branch Library consists of the main library with a staff of three professional librarians, four clerks and a typist; there is a branch library in the Physical Metallurgy Division with a library clerk in charge, an active collection at the Mining Research Laboratories, Elliot Lake, with a clerk in charge, and a collection at the Western Regional Laboratory in Edmonton with a technician in charge. Further library services will be needed as the various divisions move out to the Corkstown Road site during the next few years. Since the main library will probably be the last to move, another branch library will be established there to serve the various divisions in the interim.

Subscriptions to more than 831 journals, and purchases of monographs, textbooks, abstracting and indexing services, are supplemented by publications acquired through exchange agreements with scientific and technical societies in all parts of the world.

The library's serials are publicized by means of the National Science Library's Union List of Scientific Serials in Canadian Libraries, and its books in the Union Catalogue of the National Library. In addition, our holdings are now announced in the Comprehensive List of Periodicals for Chemistry and Chemical Engineering published by Chemical Abstracts Service, Columbus, Ohio.

The shortage of trained professional staff continues, though not as severely as before.

Circulation during 1968-69 reached 53,711 items, an increase of 7.5 per cent over the previous fiscal year. The number of books and journals in the library stands at 77,000 and that of documents at 10,800.

Observatories Branch

The Observatories Branch is involved in two major disciplines—astronomy and geophysics. Astronomy is studied in major observatories at Ottawa, Penticton and Victoria, and at a number of field stations. The proposed 156-inch Queen Elizabeth II telescope, which was to have been placed on Mount Kobau in south-central British Columbia, was cancelled during the year by government decision, but site-testing is continuing and the site will be maintained for the installation of smaller telescopes.

There are three geophysics divisions: Seismology, which operates 29 seismograph stations plus an array for the detection and identification of nuclear explosions, and sends out field parties in all parts of Canada; Geomagnetism, which studies the present and past geomagnetic fields through 11 permanent observatories and a major laboratory, and which conducts field surveys in all parts of Canada; and Gravity, which is involved in field work in all parts of Canada.

Stimulated by exciting advances in the space age, public interest in astronomy has shown a marked increase. Over 10,000 visitors were registered at the Ottawa Observatory during the past year, about half at the regular Saturday evening program, the remainder in the 125 specially arranged group tours. A further 100 requests for tours had to be refused. The Victoria Observatory is even more popular with the public, receiving about 37,000 visitors throughout the year, most of them during the daytime when they view the 72-inch telescope and a small museum; some of them on Saturday nights when they are permitted to see through the telescope. The Radio Astrophysical Observatory at Penticton discourages visitors since the ignition system of cars interferes with the operation of the telescope, but regular visiting hours are established on Sunday afternoons during the summer. No record is kept of the numbers who attend.

The large volume of written requests received from individuals and school groups for information on astronomical questions is being met by a series of printed leaflets prepared by the Dominion Observatory, Ottawa. This service is slowly being extended to cover geophysical topics as well.

ASTRONOMY DIVISION—OTTAWA

The Time Service, comprising the time laboratory and the CHU transmitters, has been modified according to a long-range plan to provide a Canadian standard of time and frequency acceptable to both the scientific and layman user. The second of the proposed new transmitters was acquired and the second of three vertical antennas was erected to radiate the signals more efficiently. The transmitter site was turned over by the Department of Transport to the Department of Energy, Mines and Resources. The purchase of the second of three required caesium atomic standards, and the replacement of outdated equipment with modern solid-state circuitry, has made the Time Laboratory a centre where time may be resolved to the tenth of a microsecond. Correct time is distributed to a variety of users: The Bell Telephone Company, the R.C.M.P., the C.B.C, and various government laboratories have direct lines to the time lab; Observatory time is required to mark the official closing of tenders on government contracts; the radio time signal is recorded continuously by the Montreal Police Department on the tape recording of official dispatches.

The Mirror Transit Circle, a transit telescope employing features of modern technology such as photography and remote servo control, has been under development at the Dominion Observatory since 1954. It was intended to replace the Meridian Circle, which had outlived its usefulness in the determination of fundamental star positions. When it was brought into operation in 1968 it showed an unsuspected sensitivity to thermal effects. By the end of the year it became increasingly apparent that in its present form it was not a practical telescope. The additional research to make it functional will require specialized engineering and additional funds, both of which will have to await a more favourable economic climate. Meanwhile, data are still being accumulated so that a scientific report on the instrument may be submitted to the astronomical community.

On May 18, 1968, the Photographic Zenith Tube Observatory at Calgary was inaugurated with scientific representation from the U.S. Naval Observatory and the Royal Greenwich Observatory. The installation is successful; many plates have been secured and the measurement of them is proceding. The Ottawa PZT site was operated on 194 nights for a total of 3,436 transits, all of which have been measured and the results forwarded to the international coordinators for time and polar motion.

The Meteorite Observation and Recovery Project (MORP) established its headquarters at the University of Saskatchewan in Saskatoon in 1968. Three of the proposed 12 camera stations were constructed during the year and testing of the instruments in the first station was well advanced by the spring of 1969. Much of the instrumentation for the remaining stations has been ordered.

The Meanook-Newbrook observatories continued their active program of meteor spectroscopy. The analysis of these spectra is conducted in Ottawa, and three papers on meteor astronomy were published or submitted for publication during the year.

A peninsula on the Ottawa River at Shirley's Bay has been selected as the most suitable Canadian site for

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a small solar observatory as the result of a site survey commenced in 1966, during which 100,000 fine-scale images of the sun were recorded. A contract for mechanical construction of the spar telescope was awarded to Canadian Westinghouse Ltd., Hamilton, Ontario. Installation of optics and electrical control systems will be performed in the solar laboratory at the Observatory. Plans for the development of the site, including the observatory building and the road, have been prepared for implementation during 1969-70.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY

This Observatory studies stars and interstellar space through their radio emissions. It operates three major telescopes for the purpose—a conventional 84-foot "dish" tuned to 1,420 MHz, and two arrays operating at 22 MHz and 10 MHz respectively. It is in process of constructing a "super-synthesis" telescope, which will consist of two "dishes" mounted on railway lines in such a way that the distance between them can be varied; tenders have been called for the construction of the movable towers and the design of much of the equipment is well advanced.

The main research projects of the Observatory have been concerned with the low-frequency spectra of radio sources, the distribution of nearby galactic neutral hydrogen, the structure of ionized hydrogen regions, quasar angular diameters and pulsar intensity fluctuations.

Survey observations with the 22-MHz array have been completed for the whole sky visible from Penticton. Observations of 200 radio sources have been analyzed for spectral flux densities. These are being compared with similar 10-MHz measurements in a detailed study of spectra. A study of the low-frequency absorption due to ionized-hydrogen regions as observed at 22-MHz and 38-MHz yielded new measures of the kinetic electron temperatures in these regions. An analysis is being made of the association of radio sources having steep low-frequency spectra with clusters of galaxies.

Long-baseline-interferometer experiments were conducted between this Observatory and Prince Albert (Saskatchewan) and at Parkes (Australia) to determine the angular diameters of quasars. A long-baseline experiment utilizing the 22-MHz array and the 46-M paraboloid at the Algonquin Radio Observatory detected the bursting radiation from the planet Jupiter and indicates a source diameter less than 2 per cent of the diameter of the planet. A new hydrogen maser has been acquired for the long-baseline interferometer which permits more accurate time keeping.

Observations with the large 10-MHz array have continued through the winter nights of 1968-69. Reduction of the observations will yield a map of a large region of the northern sky. In addition to studies of individual galactic sources, the maps will be useful in determining the amount of diffuse ionized hydrogen in the galactic disc.

Data obtained from the neutral hydrogen line profiles observed at intermediate galactic latitudes with the 25.6 paraboloid and the 100-channel spectrometer were analyzed to study the distribution of random motions of gas in the solar vicinity.

Considerable effort has been devoted to the study of pulsars. Although our paraboloid is small compared with others which have been used for these weak sources, several investigations are in progress, including a study of intensity variation.

Reduction of data from the 1,420-MHz continuum survey has continued, and maps have been prepared of large regions of the sky.

Experiments on radio pulses from cosmic-ray air showers are continuing in collaboration with the University of Calgary. A new 22-MHz array, pointing magnetic north-south, is being built.

The Observatory has undertaken a feasibility and design study in cooperation with the University of Alberta for a large low-frequency array to be ready for operation by the next sunspot minimum. The instrument, which will operate at a frequency of about 13 MHz, will extend our current work at 10 and 22 MHz to much fainter sources. A site has tentatively been located in the valley of the Clearwater River in the Alberta foothills.

DOMINION ASTROPHYSICAL OBSERVATORY

This year marked the fiftieth anniversary of the opening of the Dominion Astrophysical Observatory as the major Canadian observatory for researches on the structure of the galaxy and physical studies of the stars and planets. To celebrate this occasion, the 127th meeting of the American Astronomical Society was held at Victoria and a special issue of the *Journal of the Royal Astronomical Society of Canada* was prepared with articles giving reminiscences of early days at the Observatory and describing present and past

research. A display showing photographs taken during construction of the Observatory was set up in the exhibit room for the 37,000 visitors.

New instrumentation for the telescopes continued to increase their efficiency and to make these telescopes comparable to any except the very largest in the world. New 6-inch secondary mirrors for the 48-inch telescope with special high-reflectance coatings replacing 16.5-inch mirrors involved a new concept which will probably be important in the design of future telescopes. In order to achieve maximum efficiency three sets of three small mirrors were made and installed in special turret mountings which could be rotated to reflect the wave-length region required; the change-over also involved a special prism-lens system to change the focal ratio of the telescope. The new system was installed in March, and excellent results are being obtained. Designs have also been completed to improve the 72-inch telescope at the focal plane, with new slits for the spectrograph and new viewing eye pieces to facilitate the observation of the faint stars that can now be studied, and to improve the field for objects shown to the visitors.

Important results that have been obtained from studies of stellar spectra during the past year include those noted below.

New observations of reddened, distant stars have been compared with unreddened, nearby stars with the use of the new low-resolution scanner in the blue region of the spectrum. Discontinuities in the curve relating energy with wavelength have been detected near the still unidentified interstellar line at 4,430A., and they may be produced by other lines; these results may assist in the identification of molecules in interstellar space.

A high-resolution scanner was used to observe the spectrum-line profiles of supergiant hot stars. Changes in the line shapes have been detected in nearly all of these stars, sometimes in minutes, sometimes in days or weeks. It has been concluded that these observations are related to matter being ejected from these atmospheres, which seems to be a phenomenon common to all bright, hot stars. Models for hot supergiant stellar atmospheres expanding at several thousand km/sec have been computed for comparison with observations recently obtained from rockets in the far ultraviolet region of the spectrum.

Mass motions have also been detected in two interesting binary systems. Major changes have been observed in profiles of the hydrogen lines in the spectrum of the close binary system *U Cephei,* which has a period of 2½ days. These changes may be related to emission and absorption by the gases streaming between the components and may also be related to asymmetries in the light curve. A somewhat similar study is being made of the long-period (20 years) system *VV Cephei.* Analysis of the hydrogen alpha line shows that the hot secondary star has a gaseous envelope surrounding it, which appears as emission; the radial velocity changes observed for this line suggest that the system is rather less massive than indicated by other investigators, each star having a mass about twenty-five times that of the sun. The observations also indicate that a stream of gas is flowing from the extensive atmosphere of the cool primary star towards the hot secondary star.

The less massive but somewhat similar system of *32 Cygni* underwent eclipse in September and a series of 60 high-dispersion spectra were obtained between June and November. Preliminary analysis of the spectra confirms the presence of gas clouds of ionized calcium in the extensive atmosphere of the primary star. Examination of the spectra obtained during total eclipse indicates that this star, while having a very extensive atmosphere, may not be as luminous as had previously been thought.

In many binary systems such as Algol, the light from one star reflected from the other affects the shape of the light curve obtained near eclipse. Extensive computations are being made to determine the geometric elements of such systems and the temperature distribution over the heated stars from precise observations of the light variations.

Theoretical computations of processes taking place in model stars with masses fifty times that of the sun (about the limit for stability) have been made as the star evolves from the main sequence through the helium-burning stage. Rather large changes in luminosity occur as the temperature of the atmosphere varies, and these changes are considered to be the result of incipient instability characteristic of the large mass.

A statistical study of massive binary systems showed that the most massive system with completely determined masses is *V382 Cygni* whose components are 32 and 37 times that of the sun. The most massive system is probably Plasketts' star for which the components are inferred to be 50 solar masses each.

A one-day conference of well-known astronomers interested in the structure of the galaxy was held at the

Observatory following the meetings of the American Astronomical Society. The group strongly recommended that spectroscopic observations of the hot B stars at the Dominion Astrophysical Observatory be extended to the fainter limits now possible with the more efficient spectrographs. These should be accompanied by photometric observations and should be related to data obtained from radio telescopes. The greatest effort should be spent on regions where ionized hydrogen is present and which are related to the spiral arms of the galaxy, and on stars at distances more than six thousand light years. These recommendations will be implemented as well as possible, and observations of stars in the ionized hydrogen regions have begun.

Although capital expenditures on the 156-inch telescope have been halted, a consortium of Western Universities (WESTAR: Western Telescope for Astronomical Research) has been formed to seek funds to continue the project and has been given the 156-inch mirror blank and the large grinding machine. The design and optical staff assembled for the project has been transferred to the Dominion Astrophysical Observatory, but has been given permission to work with the University group as required.

Astronomical observations on Mount Kobau have been continued. A 16-inch Bollér and Chivens reflecting telescope was installed in April 1968, and 3,500 observations of standard stars and stars in clusters and associations were made with a four-channel photometer with a data acquisition system. The data have been reduced with the aid of the University of Victoria computer and will soon be ready for publication. A Polaris Image Monitor built at the Dominion Observatory was installed in August. Results obtained during the winter gave a good correlation between image motion measured with the image monitor and visual observations that have been made since June, 1967. It seems probable that previous estimates of seeing conditions on Mount Kobau have underestimated rather than overestimated the quality of the site. From July 1967 to March 1969, 184 nights were completely clear, 188 partly clear and 268 cloudy, with 2,326 hours considered observable. Thus, Mount Kobau must be considered a good astronomical site with the number of observable hours almost equal in summer and winter.

SEISMOLOGY DIVISION

New seismic observatories equipped with short- and long-period instruments were commissioned at Inuvik, N.W.T., and Port Arthur, Ontario. The latter station is operated by contract with the Department of Geology, Lakehead University. These two new observatories complete the development of a modern network of 25 widespread, fully instrumented seismic observatories throughout Canada, and represent the completion of the first stage of a program approved by the government nearly a decade ago. This network is complemented by four second-order local stations for more detailed study of Canadian seismicity. The seismic observatory program can now move into its second stage of continuous instrumental updating and calibration, with extension and modernization of data-handling and distribution services to keep abreast of the growing demands for seismic data and records.

The strong motion network in western Canada continued operation for earthquake engineering purposes: 14 stations are fully equipped and 57 locations have been instrumented with seismoscopes for detailed ground-acceleration studies under different foundation conditions.

In consultation with the National Committee for Earthquake Engineering, the basic decisions have been taken with respect to the revised earthquake zoning map for Canada for the National Building Code Revision of 1970, and the map has been produced. The technique and rationale used have been described in several papers published in the learned journals.

The largest earthquake in Canada during the year was magnitude 5.1 approximately 200 miles north and slightly west of Victoria. The usual number of minor shocks were reported in both eastern and western Canada. Micro-earthquake field studies were made in a volcanic region of northern British Columbia and in an area north and east of Quebec City, where differential vertical crustal movements have been defined, near to the La Malbaie centre of seismic activity in eastern Canada. Data reduction is continuing, but it is clear that few events can be associated with the volcanic area, although 8,000 micro-earthquakes have been detected from sources along the British Columbia-Alaska border. In eastern Canada fewer micro-earthquakes were observed than expected. These reconnaissance-type experiments have established clearly the technical requirements for experiments of this kind, and demonstrated the feasibility limits in Canada.

Quantitative earthquake-risk estimates were given on demand to engineering and insurance companies, and international exchange of seismic data continued on schedule and at a high level. An increase towards

the end of the year in public concern regarding earthquake risk should be noted, following the California patterns of prophecy, and considerable effort has been made to educate the general public in this respect.

Considerable progress was made in research into the problems of the detection and identification of underground nuclear explosions. Papers have been published on the positive identification levels achieved with the Canadian installations using a technique involving the relative excitation of long-period surface waves by an underground explosion and by an earthquake in the same general area. A continuing telemetering experiment was carried out at the Yellowknife array in order to evaluate a radio-linked system which will soon be necessary to replace the extensive, very old cabling on the array. Another long-period high-gain seismic field installation was made in Yellowknife. The data from these long-period installations at Yellowknife will allow scientific tests to be made of the applicability of the criterion for distinguishing earthquakes from underground nuclear explosions. These tests will make possible firm predictions about the lower limit of applicability, possibly in case that a major long-period array be established. The Division was represented at the international meetings held in Sweden in 1968 under the auspices of the Swedish International Institute for Peace and Conflict Research which produced a major report for governments, on "Seismic Methods for Monitoring Underground Explosions."

Other seismologists have continued research into the mechanism of earthquakes, surface-wave dispersion in Canada, the structure of the earth's core and into the character of seismic body-wave arrivals including synthetic seismograms.

The crustal group completed a radical re-interpretation of the data from the 1965 Hudson Bay experiment, and an interpretation of the crustal characteristics under the Yellowknife array. The reduction and interpretation of data from experiments in 1966 and 1967 was advanced. The group also carried out a large-scale crustal project in north-central Quebec along and on each side of the front separating the Superior and Grenville Precambrian Provinces. Three parallel reversed-refraction lines more than 400 km long were shot, and the University of Western Ontario, Dalhousie University, the Nova Scotia Research Foundation and the Geological Survey of Canada participated in a very successful project.

The heat-flow group drilled three holes in northern Ontario across a major geophysical feature, and continued measurements in mines and drill holes throughout Canada. Measurements were made on two lakes on Ellesmere Island, and from the ice in the western Arctic. Conductivity equipment and techniques in the laboratory were much improved, and further progress made in the preparation and interpretation of observations for publication.

During the year, a re-examination of the scientific programs under way was completed and background discipline papers in seismology and in heat flow prepared for the Science Secretariat, after considerable circulation and discussion within the geophysical community in government, universities and industry.

GRAVITY DIVISION

The first phase of the adjustment of the Canadian Gravity Net has now been completed with the adjustment of all excentres at key stations of the net. The second phase, that of plotting and editing some 12,000 ties between control stations, has been under way for several months. The final adjustment should be completed in late 1969.

The Canadian contribution to the First Order World Gravity Net (FOWGN) has been edited and adjusted and is now ready for inclusion with the available data from other participating countries. The joint U.S.-Canadian project for adjustment of the FOWGN has been postponed pending development of new editing and adjustment programs incorporating several new features.

At the request of the oil-exploration industry a gravity-calibration line extending from Cardston to Edmonton, Alberta, was established in the spring of 1968 using four LaCoste and Romberg land gravimeters. The 25 calibration stations cover a 500-mgal range in gravity.

Measurements on the North American Calibration Line with the Canadian Pendulum Apparatus have been successfully completed. The observations were made at Ottawa, Fairbanks, Edmonton, Denver and Mexico City and return in reverse order.

A system for the storage and retrieval of gravity data is now operational at the Gravity Division. A data file consisting of approximately 120,000 discrete gravity observations has been stored on magnetic disc, and can be extracted with the use of programs written for an IBM 360/65 computing system. With this system, the Gravity Division is now able to fill requests for data from both external institutions and from within the Division.

The new *Gravity Map of Canada* (scale of one inch to 40 miles) was published in September 1968 and is now available from the Map Distribution Office of the Surveys and Mapping Branch, Ottawa. All gravity data collected up to January 1, 1967, have been incorporated in the map.

A full program of field measurements was completed during the year. The investigations included the following areas:

(i) Regional gravity mapping of the Cordillera was completed between longitudes 114 and 121 and latitudes 49 and 51 and in the vicinity of Williams Lake. Stations observed numbered 565 at grid survey points supplied by the Surveys and Mapping Branch and the Mapping and Charting Establishment, Department of National Defence.

(ii) During the September 1968 cruise of the CSS *Parizeau,* of the hydrographic fleet, geophysical measurements along the Red Deer-Revelstoke-Victoria Cordilleran section were extended 300 nautical miles offshore with surface-gravity, magnetic and bathymetric measurements along lines ten nautical miles apart between Cape Flattery and Cobb Seamount.

Similar measurements were made along lines three nautical miles apart in the Strait of Juan de Fuca. In the Strait of Georgia and off the west coast of Vancouver Island between Cape Flattery and Ucluelet continuous seismic profiles were made on lines two nautical miles apart in addition to the gravity, magnetic and bathymetric measurements. The lines west of Vancouver Island were 70 nautical miles long extending from the coast to the foot of the continental slope.

(iii) More than 1,000 gravity stations were observed between Schefferville and the Labrador Coast.

(iv) Regional gravity coverage has been completed in the Kenora, Red Lake, and Sandy Lake areas of Ontario and along the shores of Lake Winnipeg, with the addition of 1,125 gravity stations during 1968.

(v) Regional gravity measurements in Lake Ontario and Lake Erie in 1968 totalled 272. The survey will be completed in 1969.

(vi) In 1968 about 950 gravity stations were established over the sea ice covering an area of about 60,000 square miles of the Arctic Ocean and 25,000 square miles of M'Clure Strait. In Baumann Fiord, Ellesmere Island, 163 gravity stations were observed over the sea ice.

(vii) A bench-mark survey was carried out in Nova Scotia, Prince Edward Island and New Brunswick. Some 800 stations were observed using LaCoste and Romberg meters.

(viii) Some 680 stations were established along roads in southern Manitoba. An elevation meter was used in this survey and the elevations obtained have an accuracy of better than ± 2 ft.

(ix) Some 650 stations spaced at intervals of one to three km were observed over the Morin Intrusion, Quebec, using road and helicopter transportation. A detailed study of this intrusion is in progress in co-operation with the Geological Survey of Canada.

Interpretational studies of the regional gravity anomalies in the following areas have been completed or are nearing completion: Timmins-Senneterre area, Burleigh area, Bear and Slave geological provinces, Coppermine, northern Saskatchewan, Gulf of St. Lawrence, Kinmount Geophysical Test Range, Ontario, Hudson Bay, Queen Elizabeth Islands and Arctic Continental Margins.

Recent studies of the isostatic response of the crust in Canada to loading show that the country is isostatically over-compensated due to incomplete recovery of the lithosphere from the displacement caused by the Pleistocene ice loads. The amplitudes of the free-air anomalies suggest that a substantial amount of uplift has yet to occur.

The recognition of the Charlevoix (La Malbaie), Quebec, crater and the Mistastin Lake, Labrador, crater raises the number of known ancient meteorite craters in Canada to sixteen. Gravity data are available for fourteen of these craters, notably for the Manicouagan and Sudbury structures, and are currently being interpreted.

A set of V/M horizontal pendulums has been operating continously during the past year at a mine site north of Ottawa and a second set of horizontal pendulums will be installed in the mine by the end of the year. The LaCoste and Romberg earth-tide gravity meter has been operated intermittently for several months in Ottawa and will be eventually installed at the mine site.

GEOMAGNETISM DIVISION

The Geomagnetic Division is responsible for producing charts showing the direction and intensity of the geomagnetic field over Canada and the neighbouring oceans, and for the magnetic information which appears on aeronautical and marine charts. The magnetic charts are based on measurements made in an

aircraft by an instrument designed and operated by scientists of the Division. In early 1969, British Columbia and the northeastern corner of the Pacific Ocean were surveyed in a pattern of parallel flight lines, 20 miles apart over the land and continental shelf, and 40 miles apart over the deep ocean. The total distance travelled in a chartered DC-6 aircraft was over 67,000 miles.

Magnetic charts must be revised every five years because the geomagnetic field is constantly changing. To bring the data from earlier airborne surveys up to date, measurements are made on the ground every few years at each of 100 carefully marked repeat stations, uniformly distributed over the country. During 1968, 25 such stations were occupied in Quebec, Ontario, Manitoba and the Arctic Islands.

Variations in the direction and intensity of the geomagnetic field were recorded continuously at magnetic observations in the following locations: Alert, Mould Bay, and Baker Lake, all in the Northwest Territories; Meanook, Alberta; Victoria, British Columbia; and Agincourt, near Toronto. Two new magnetic observatories began regular operation in June, 1968, at St. John's, Newfoundland, and at Ottawa. Agincourt magnetic observatory, which had recorded continuously at that location since 1898, was closed on April 1, 1969, because of artificial disturbance due to industrial activity and highway construction.

The move to the new Geomagnetic Laboratory at Blackburn, 10 miles east of the Dominion Observatory, was completed in May 1968. The facilities include a main building, housing offices and laboratories for instrument development, and 15 small non-magnetic buildings, separated at least 200 feet from each other, on a tree-covered site of 200 acres. The small buildings provide for the magnetic observatory and improved facilities for testing new instruments, for paleomagnetic research, and the training of staff.

It is hoped that the Blackburn site will be unaffected by artificial magnetic disturbances for many years. A favourable sign is that the federal Department of Forestry has acquired some 1,000 acres of land surrounding the site, to be used in tree-growing experiments to last a century or more.

Analysis and interpretation were completed of the variations of the magnetic and earth-current fields recorded at several locations in Ellesmere Island in 1967. A zone of unusual electromagnetic induction has been traced across the island, from Alert in the northeast to Greely Fiord in the west. The only possible explanation appears to be a long massive body of very high electrical conductivity, lying near the base of the crust. Further field work was planned for 1969 to trace the extension of the anomalous zone, to both east and west.

Similar observations obtained in southern British Columbia in 1967 confirm that a highly conductive layer exists near a depth of 30 km to the west of the Rocky Mountain Trench, while there is no evidence for such a layer to the east. The structures of the deep crust and upper mantle under the eastern and western Cordillera are evidently quite different.

Research in paleomagnetism in 1968 produced three results of general interest: the recognition of diagenetic magnetization processes in red beds and the development of techniques for their analysis; a study of the intensity of magnetization of basalts, which contradicts the proposed correlation between oxidation state and polarity; and strong evidence for the occurrence of polar wandering, based on the inconsistency between the motions deduced paleomagnetically for the ocean floors and the continents. Good progress was made in the instrumentation of the new paleomagnetic laboratories.

Polar Continental Shelf Project

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Arctic coast of Canada, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Arctic Archipelago and the waters between them, and other areas that may be of special interest. The Project serves in part to facilitate the Arctic researches and surveys of other units of the Department of Energy, Mines and Resources; in part it carries out, with its own personnel, work that is unique within the Department; it also serves as the vehicle through which the investigations of other government agencies are carried

out in the Arctic Archipelago and the Arctic Ocean; and it provides facilities and support for approved university researches in the area.

The Project's field-survey and research activities will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean that are of interest to Canada and which can be reached with available logistics, and those parts of the archipelago and the mainland not studied by other agencies of the department. From 1959 to 1968 work has been concentrated in the region between Meighen Island and Banks Island, extending about 250 kilometres out to sea and the same distance back into the islands. Individual surveys and researches have been carried out throughout the Queen Elizabeth Islands and extended to the Mackenzie River Delta and Beaufort Sea in the southwest, and northern Greenland in the northeast.

Field activities in 1968 were carried out from late February to early November, and were coordinated mainly from Mould Bay, on Prince Patrick Island, and from Resolute, on Cornwallis Island. Approximately 100 persons were engaged in investigating the region of the continental shelf west of M'Clure Strait, and the adjacent islands and straits. Other work ranged over the Arctic Ocean from the Beaufort Sea to the Lincoln Sea, in the interior of many of the Queen Elizabeth Islands, and in the Mackenzie River Delta. Supporting activities such as transport and construction engaged for brief periods about 40 persons in addition to those employed directly on the field investigations and surveys.

In addition to the Department of Energy, Mines and Resources, nine other agencies were involved in or received assistance from the operations of the Polar Continental Shelf Project. Among them were five universities (one American), and Canadian government departments.

In 1969 (whose field season began toward the end of the fiscal year under review) the main emphasis of regional surveys was to be shifted from the western archipelago to the Beaufort Sea - Mackenzie Delta region.

The following is a summary of the work done in 1968, by major scientific field.

Aeromagnetic Survey—Measurements of the total residual magnetic field were made from a height of 330 metres over the continental shelf and continental slope west of Prince Patrick Island and M'Clure Strait, and over western M'Clure Strait. Approximately 39,000 line-kilometres were flown.

Geodetic and Topographic Surveys—Difficulties in interpreting some of the geophysical measurements made in 1967 led to a careful examination of Decca Lambda positions, in which the latitude and longitude of 28 stations extending seaward to 300 kilometres were determined accurately by repeated solar observations. This is believed to be the first large-scale test of the accuracy of low-frequency electronic positioning over an ice-covered ocean surface.

Geology, Marine—Samples of bottom sediments were obtained offshore from the western entrance to M'Clure Strait and adjacent parts of the continental shelf. These samples and collections are being studied in the laboratory for evidence of their age, source, conditions of transport and sedimentation, indications of change in sea level, and variations in climate in the geologically recent past.

Geology, Terrestrial—Logistic support was provided to parties from the Geological Survey (q.v.).

Geomagnetism—The Project provided the field support for repeat measurements of the magnetic field by members of the Observatories Branch at permanent magnetic stations at Cambridge Bay, Grise Fiord, Holman Island, Inuvik, Isachsen, and Winter Harbour.

Glaciology and Glacier Physics—A detailed study was started of the Meighen Island icecap to determine the energy relationships of the icecap, its relation to local climate, and its behaviour in the recent geological past. Meighen Island icecap has been studied annually since 1959. The relation between temperature and internal strain in the icecap was studied by means of a borehole that penetrates its entire depth. Measurements continued of the mass balance of the icecaps on Melville Island, which are the thinnest and driest of North American arctic glaciers.

Gravity—The regional gravity survey was continued over the continental shelf and slope offshore from Prince Patrick Island and M'Clure Strait, an area of 135,000 square kilometres. In addition, 75 gravity stations were completed in the Baumann Fiord area of southwestern Ellesmere Island.

Heat Flow—Measurements were made of the flow of geothermal heat from the floor of the ocean near the west end of M'Clure Strait. Five shallow oceanic and one borehole station were completed in this study.

Hydrographic Surveys—A detailed hydrographic survey of a small part of Great Slave Lake was undertaken at the request of the Department of Indian

Affairs and Northern Development to aid engineering studies for a proposed water-supply system. Survey personnel made 450 depth measurements through the ice. A regional bathymetric survey was carried out west of Prince Patrick Island and M'Clure Strait, and over western M'Clure Strait, by spot sounding through the ice. A systematic hydrographic survey was made of Baumann Fiord, southwestern Ellesmere Island, by spot soundings through ice.

Oceanography—Field support and equipment were provided for a study of the oceanographic conditions in the spring in Kane Basin, between Ellesmere Island and Greenland. Owing to a combination of natural and transportation difficulties, no useful scientific results were obtained; but the experience should help in planning future surveys.

Sea-Ice Studies—Systematic patrols were made of all major waters of the Queen Elizabeth Islands and of the adjacent Arctic Ocean and Parry Channel throughout the period of significant sea-ice activity. Information was collected on the nature, break-up, amount, distribution, disposal and formation of the sea ice and of certain tabular icebergs or "ice islands." These surveys, which have been carried on for a number of years, may lead to a better understanding of the causes and controls of sea-ice development and movement and, in turn, to better forecasts of ice conditions.

Miscellaneous—Support was provided for a number of studies, by other agencies, such as: a survey of insect life of central and northwestern Banks Island; an ethological study of the fauna of Bathurst Island, with particular attention to the relationship between wolves and muskox, the competition between various grazing species, the courtship and territorial behaviour of ptarmigan, and the breeding cycles of shore birds; a survey of the distribution of vegetation on Fitzwilliam Owen Island and a study of lichens, mosses and peat on Prince Patrick Island and Meighen Island; a study of the marine botany along the shores of several islands; and others.

MINERAL DEVELOPMENT GROUP

Mineral Resources Branch

The Mineral Resources Branch was formed from the previous Mineral Resources Division on October 1, 1968. It is organized into three Divisions—Research and Planning Division, Commodities Division, and Taxation and Legislation Division—with technical and administrative support groups. Most Branch projects are carried out on an interdivisional basis to ensure that each receives the professional contribution of various disciplines essential to its successful completion.

The Mineral Resources Branch conducts research on mineral policy and makes recommendations thereon. It conducts fundamental and applied research and field investigations into the economic and technical aspects of mining and mineral trade in a regional, national or international context. The work covers all aspects of the mineral industry from resources through exploration, development, production, processing, transportation, and consumption, and results in various types of reports.

ADVISORY AND CONSULTING SERVICES

The Mineral Resources Branch provides mineral-industry information to senior officers of the department and other government departments. These studies serve as a basis for policy decisions of the federal government and agencies and, upon request, provincial governments and agencies.

Regional Studies in Canada

A detailed report, *Mineral Resource Development, Province of Nova Scotia,* was prepared during the year at the request of the Atlantic Development Board. It was similar to those completed in 1966 on the province of Newfoundland and Labrador and in 1967 on the province of New Brunswick. The Nova Scotia report reviews and discusses the province's mineral industry in six chapters and outlines the direction that assistance by government, federal and provincial, might take to accelerate mineral-industry growth. At the Board's request, a consolidated report summarizing the findings and proposals of the three provincial studies was completed by the end of the fiscal year.

A report, *Mineral Industry Development in Manitoba to 1980,* was prepared at the request of Manitoba's Targets for Economic Development Commission (TEDCO). The provincial commission was formed to assess the outlook for Manitoba's economy and to make recommendations for the over-all economic development of the province. The Mineral Resources Branch provided an analysis of the mineral industry with forecasts of output, employment and investment; pointed out development opportunities; and examined such factors as government activities and potential infrastructure investments.

A preliminary analysis by the Branch on the outlook and problems of mineral development in northern Saskatchewan to 1980 was also completed. It was undertaken at the request of the Department of Forestry and Rural Development (FRED) as part of a total resource-and-economic appraisal that may result in a federal-provincial agreement for a comprehensive regional development program. A study was initiated late in the year on British Columbia's mineral industry at the request of British Columbia's Department of Mines and Petroleum Resources.

Northern Development

The Branch continued to give advice on mineral matters to the Department of Indian Affairs and Northern Development and to participate in interdepartmental activities concerned with northern economic development. Previous special studies concerned with regional economic mineral appraisals, mineral development opportunities, and possible infrastructure investment requirements were reappraised as circumstances changed. As representatives on various interdepartmental committees, Branch officers prepared special studies such as those on Canadian access requirements to tidewater on the Pacific Ocean, the economic mineral potential of the Yukon Territory and the District of Mackenzie as the basis for the development of a 10-year, $100-million northern-roads program, various mineral-property evaluations for appraisal of access-road programs, and the continuance of field investiga-

tions by mineral economists to advise on developments and outlook. Planning and research were initiated late in the year for a major comprehensive study on economic and transportation (rail and road) requirements to assist in broad economic development of northern British Columbia and Yukon Territory. The Department's responsibility for national energy development and economic policies required particular attention because of the discoveries of large petroleum resources in the far north of Alaska near Yukon Territory and the exploration and development undertaken on Canada's Arctic slopes and islands, with attendant transportation and marketing problems.

Science Policy

The Branch prepared several briefs on science policy as it relates to the mineral industry and the various disciplines and training associated with it. The topic has become of national as well as international concern as governments attempt to improve the decision-making process for allocation of resources to scientific research and the direction of economic objectives.

Interdepartmental Commodity Committees

The Branch is represented on a large number of interdepartmental commodity committees studying mineral-commodity problems of an industry, a region, or the nation. The committees usually meet on an *ad hoc* basis but may be regular and continuing. Of the latter type was the one formed to assist in the allocation of nickel to Canadian consumers during the nickel shortage. Consumers were limited to the amount of their 1966 purchases from domestic suppliers, a system that threatened to cause hardship for certain consumers. The committee therefore reviewed requests for increased amounts and made recommendations for justified needs to be satisfied from domestic production. Problems related to several other commodities (copper, iron ore, potash, uranium, coal, lead and zinc, aluminum, petroleum) were studied by interdepartmental committees on an *ad hoc* basis, those related to uranium controls, regulations, and stockpiling being of particular moment.

Taxation

Analyses and recommendations were provided to the Department of National Revenue with respect to tax benefits under the Income Tax Act which are applicable to the mineral industry. Reports were prepared on 24 applications for three-year tax exemptions, two applications for the special oil-pipeline depreciation allowance, and two applications for research grants under the Industrial Research and Development Incentive Act.

Advice was provided to the Department of Indian Affairs and Northern Development in the drafting of a proposed revised Yukon Minerals Act. These advisory services included both taxation and legislative matters. Study of the report of the Royal Commission on Taxation and its implications for the Canadian mineral industries was continued. Preliminary investigations were started on the degree of foreign ownership and control of the Canadian mining and mineral-processing industries, together with an assessment of benefits to Canada, and the behaviour of foreign companies as corporate citizens of Canada.

General Advisory and Consultative

As a result of the continuing in-depth study and analysis of all mineral commodities and subjects by its staff, the Branch provides information and advice on a broad scale to mineral-industry representatives and the general public through office interviews, correspondence, telephone and publications.

INTERNATIONAL ACTIVITIES

The Branch continued to participate in intergovernmental organizations and international associations that embrace mineral-industry matters. Canadian government representatives are provided with documents and studies; in some instances, officers of the Mineral Resources Branch attend the respective meetings.

An officer of the Branch represented the Department on the Canadian delegation to the International Lead and Zinc Study Group and attended the 12th Session in Geneva, in November 1968. The Branch contributed to the technical-economic studies and to the statistical services of the Study Group. It continued to review the trends in the world tin industry and participated in matters of concern to the Third International Tin Agreement to which Canada is a consumer signatory. Statistical data on Canada were also supplied to OECD groups including the Special Committee for Non-Ferrous Metals, the Nuclear Energy Agency, and the Special Committee for Iron and Steel. Data were also supplied to United Nations Organizations such as the Tungsten Committee, and the Committee

for Industrial Development. A paper was prepared for the latter by Branch officers, entitled "Steel Plant Location in Developing Economics, a Canadian Viewpoint"; it was a contribution to the Second Interregional Iron and Steel Symposium held in Moscow. An officer of the Branch attended the 36th session of the United Nations Economic Commission for Europe's Steel Committee and participated in a study tour of Poland's steel industry sponsored by the committee.

Since Canada became a member of the OECD, the Branch has had the prime responsibility of providing extensive statistical data and various studies on Canada's iron-ore and iron-and-steel industries to the OECD Special Committee for Iron and Steel. In mid-1968, this responsibility was passed to the Department of Industry, with continued Branch participation in the work of the Special Committee, particularly in the field of mineral raw materials.

A study was prepared on Canada's uranium production, reserves, and short-term demand, for the OECD Nuclear Energy Agency as part of its world study of the subject.

PUBLICATIONS

The Branch published reports in the *Mineral Information Bulletin* series on iron ore and primary iron and steel, along with its regular preliminary annual review of the Canadian mineral industry. Also completed were seven *Operators Lists,* the 1966 *Canadian Minerals Yearbook,* the eighteenth edition of the popular Map 900A *Principal Mineral Areas of Canada,* and oil and gas pipeline maps. Work proceeded on reports on beryllium, cadmium, zinc, petroleum and natural gas, chemical fertilizers, and zirconium and hafnium.

The Branch has a continuing program of educational mineral filmstrips designed for use in high schools. The photographic library and mineral-resource records centre continued to be enlarged. The Branch contributed several sections on minerals to the *Canada Yearbook*, and prepared papers for presentation at international meetings and for publication in technical journals.

Work was completed in 1967 on a comprehensive report on nickel which will be available for distribution early in 1969. The report will include chapters on history, ore deposits and resources; exploration; mining; processing; commercial forms, properties and uses; Canadian primary industry history, corporate structure, operations, production potential, position in the economy; foreign primary industry; and world supply and demand.

FOREIGN AID

The Branch, on behalf of the Canadian International Development Agency, formerly the External Aid Office, arranged 37 technical training programs for foreign trainees and provided consultation on 12 additional applications. These programs were sponsored through the various regional plans of the agency and through the United Nations. Training takes place in some cases in the Department of Energy, Mines and Resources, as well as in private industry, provincial government departments, and university graduate schools. Fourteen applicants completed their training during the fiscal year ending March 31, 1969. At the end of the period, 21 training programs were active and 10 planned programs were awaiting arrival of candidates. In addition to these post-graduate training programs, a number of foreign undergraduates attending Canadian universities were assisted in finding summer employment and surveying instruction. The Branch also participated in the recruitment of technical advisers for overseas missions to advise certain developing countries on mineral-development policies, planning and projects.

Arrangements were also made to have foreign mineral specialists and government representatives visit, upon request, certain Canadian mining and mineral-processing companies to become familiar with the Canadian mineral industry. The foreign-aid coordinator of the Branch conducted a mineral-resource investigation in Morocco at the request of the Canadian International Development Agency (CIDA) to determine the means by which a mineral-industry-development program there might be directed.

MINERAL OCCURRENCE INDEX

The Branch maintains an index of Canadian mineral occurrences for the use of those interested in mining and mineral exploration in Canada. The index contains comprehensive summaries of location, geology, history of ownership, development, and results of development work, supplemented by map and literature references, on more than 11,000 mineral occurrences. These summaries, each on individual cards, are arranged in conformity with areas of the National Topographic System. Provision has been made for revi-

sions to the index. Along with revisions, the descriptions of over one hundred mineral occurrences were being added each month to the Mineral Occurrence Index at the end of 1968.

Agreements for the exchange of mineral-occurrence information were in effect with the Nova Scotia Department of Mines, the Ontario Department of Mines, and the British Columbia Department of Mines and Petroleum Resources. The indexing of Canadian mineral occurrences has been intermittent in the Department since before 1900 until 1959. Since then it has been continuous.

ROADS TO RESOURCES

The Roads to Resources program is a national effort designed to provide access to areas potentially rich in natural resources. The administration of the agreements, which provide $7.5 million as the federal share for each province, was transferred to the Branch in October 1966.

Federal payments to March 31, 1969, were approximately $74,650,000. The balance, some $350,000, has been committed for the completion of the program in 1969-70.

Province	*Number of roads*	*Mileage completed*	*Federal contributions to March 31, 1969*	*Termination date*	*Status*
Newfoundland	10	270.78	$7,153,577	March 31/70	—
Prince Edward Island	30	425.9	7,500,000	March 31/68	Completed
Nova Scotia	16	356.3	7,488,792	March 31/66	Completed
New Brunswick	20	271.1	7,500,000	March 31/69	Completed
Quebec	3	179.0	7,500,000	March 31/67	Completed
Ontario	8	281.6	7,500,000	March 31/69	Completed
Manitoba	5	338.8	7,500,000	March 31/67	Completed
Saskatchewan	6	455.6	7,500,000	March 31/68	Completed
Alberta	2	415.9	7,500,000	March 31/67	Completed
British Columbia	1	213.0	7,500,000	March 31/68	Completed

THE EMERGENCY GOLD MINING ASSISTANCE ACT

The Act is administered in the Mineral Resources Branch under the direction of the Assistant Deputy Minister (Mineral Development).

Inspection engineers from the Branch conduct regular inspections of gold mines receiving assistance. They report on all aspects of the mining operations that affect the assistance payable under the Act. In particular, they determine the proper classification of exploration and development expenditures, review the allowance of costs which are in question and report upon mining and milling practices and the ore reserves of the mines.

The Audit Services Branch, Department of Supply and Services, examines interim applications for advance payments of assistance and carries out the final audit of the accounting records of each applicant.

The Act was passed originally in 1948 to assist gold mines in overcoming economic difficulties caused by rising costs of production and a fixed price for gold. The legislation had the objective of extending the operating life of the gold mines and thereby allowing their dependent communities to adjust gradually to diminishing economic support.

An amendment to the Act in December, 1967, extended its operation for a period of three years to December 31, 1970.

The amount of assistance payable to an operator depends on the amount by which the average cost of production per ounce exceeds $26.50. A gold mine that has an average cost of production less than $26.50 an ounce is not eligible for assistance. When calculated on the basis of all eligible ounces produced, the maximum assistance payable amounts to $10.27 per ounce.

There were 33 lode gold mines in receipt of assistance in 1968. Assistance payments are made to the lode gold mines on a quarterly basis.

The amounts paid to gold-mine operators to March 31, 1969, for the years 1948 to 1968 inclusive totalled $261,293,250.09 on a production of 57,155,704.611 fine ounces of gold produced and sold in accordance with the requirements of the Act. The amount paid out annually has remained fairly steady at around $11 million.

Explosives Division

The high rate of fatal accidents in the explosives industry during the early 1900's emphasized the need for control over explosives, and the first Explosives Act was drafted and introduced into the House of Commons in 1911. The early recognition of the hazard and the willingness of the industry to accept controls have combined to make the explosives industry one of the safest in Canada.

The Explosives Act is primarily an act of public safety to control the manufacture, authorization, storage, sale, importation and transportation of explosives by road. Control is exercised by a system of licences and permits supported by inspections and all licences are issued from the Explosives Division office in Ottawa.

The work, associated with the issuing of licences, has increased noticeably during the past few years and as a result, the Bureau of Management Consulting Services studied the operations of the Explosives Division and made a number of recommendations which should considerably streamline the licensing operations.

One of the prime responsibilities of the Explosives Division is concerned with the manufacture of explosives. The number of factories licensed under the Explosives Act increased from 42 in 1967 to 46 in 1968. This increase was largely due to the increased interest in manufacturing explosives at the place of use and a number of factories for the manufacture of slurry-type explosives supported by bulk mix trucks and bulk pump trucks have been located on several large open-pit mines. We expect this trend to continue.

During the year, a major amendment to the regulations was introduced concerning mainly the classification and the transportation of explosives. This involved a complete revision of Part VI, the regulations governing the transportation of explosives, and a change in the classification of the "blasting-agent" type of explosives to permit the transportation of 40,000-pound loads of explosives of Class 2.

Members of the Division investigated several accidents during 1968 and although there were a number of quite serious accidents in the manufacture, and transportation of explosives none resulted in any fatalities.

One particularly serious accident occurred during the manufacture of lead styphnate at the Canadian Arsenals Limited Cherrier Plant. Here an operator suffered severe injuries to his face, shoulder and arm. Recommendations following this accident resulted in a greatly improved operation.

Another accident demolished a propellant-mixing building when 10 pounds of dry nitrocotton detonated at the Canadian Industries Limited Valleyfield Plant. Fortunately the hazard was recognized and the operation was designed as a remote-control process and as a result no one was injured.

There were nine accidents in the transportation of explosives, but only one resulted in fire or explosion of the cargo. In this case, a truck carrying display fireworks to Montreal was involved in a highway traffic accident. A gasoline fire started and one of the saddle tanks exploded. This was followed immediately by an explosion of the fireworks in the truck. Fortunately, the driver and his assistant were able to get out of the vehicle and clear the area of persons before the explosion, and no one was injured.

For transportation of explosives in vehicles operating under a transportation permit all gas tanks must be equipped with fusible-alloy safety plugs to prevent an explosion of the gas tank. This appears to be sound practice for any vehicle transporting explosives in any quantity.

Members of the Explosives Division actively promote safety programs and regularly meet with members of the industry, federal and provincial government agencies and other groups involved with the handling of explosives. The Division also has available for distribution safety literature on the storage, handling and transportation of explosives.

A separate more detailed report of the activities of the Explosives Division is published regularly.

WATER GROUP

Marine Sciences Branch

The Marine Sciences Branch produces and distributes all Canadian navigational charts and tidal information. Its surveys of the geological and geophysical characteristics of the ocean floor provide basic information for mineral exploration. Its studies of oceanographic phenomena are designed to support fisheries, transportation, coastal engineering and defence.

The Branch is organized along regional lines, with offices in Dartmouth, N.S., Victoria, B.C., and Ottawa. The headquarters is situated in the Departmental complex in Ottawa.

In 1968 the Branch fleet had twelve ships which steamed a total of 188,990 nautical miles on operations. Three chartered vessels were also employed during the year. In addition to the ships, 180 sounding launches, workboats and small craft were in service. The expansion of the fleet continued with the commissioning of CSS *Limnos* to support research on the Great Lakes. The design, contract drawings and specifications have been completed for a second Great Lakes research vessel similar to CSS *Limnos* in the continuing design program for research vehicles.

The past year has seen considerable changes in the physical appearance of the Bedford Institute at Dartmouth. An extension to the existing jetty facilities, creating a small-boat marina, was completed in late summer and a 50-per-cent expansion of the laboratory wing of the main building was completed in February 1969. The addition of two more floors to the office wing was started in late winter and was scheduled for completion in the late summer of 1969.

HYDROGRAPHY

In 1968, chart-distribution totals reached another all-time high, with 309,200 charts being distributed. The Pacific Region showed a 12-per-cent increase, largely due to the interest shown by pleasure boaters in the new Gulf Islands chart series.

During the year the Canadian Hydrographic Service published 173 navigation charts. This total was made up of 23 new charts, 8 latticed editions of new charts, 43 new editions, 75 corrected reprints, 10 reprints and 14 special charts. In addition, 50 *Catalogue Index* pages, 7 *Information Bulletins* and 4 *Pilot Index* maps were published. New editions of Volume 2 of the *Pilot of Arctic Canada,* Volume 2 of the *Great Lakes Pilot*, the *Newfoundland Pilot*, the *Great Slave Lake and Mackenzie River Pilot* and the *Gulf of St. Lawrence Pilot* were published. Six supplements to existing Pilot editions were also issued.

The highlights among the charts published were:

(a) Two new coastal and two new offshore fisheries charts of the series of coastal and fisheries charts on the Atlantic Coast.

(b) Six new small-craft charts in Ontario.

(c) Reconstructed editions of three popular charts in the Strait of Georgia.

(d) The Canadian Power Squadron's new training chart.

(e) Four charts showing Canada's territorial waters and fishing zone limits for part of the Atlantic Coast.

(f) Four special charts for the Department of National Defence.

The revisory survey program continued on the East Coast and started in the Central Region. To date, nine new editions and ten chart-amendment patches have been issued and over thirty new editions are being processed as a result of information gathered over the last two seasons. Thirty-five charts checked have not required new editions because only minor changes were found.

The Chart Production Section installed a second Monotype Photosetter and is now completely equipped for photosetting all typeset material used in its cartographic work.

Pacific Region

Primary region activities continued to be hydrographic, although significant ship and personnel support was supplied for various oceanographic work conducted by other government and university agencies. In addition, the major investigation of water-circulation

patterns within the southern part of the Strait of Georgia, which has both hydrographic and oceanographic significance, was continued.

Hydrographic surveys carried out by field parties aboard the *Wm. J. Stewart, Marabell* and *Richardson* ranged throughout the Pacific Coast and into the Western Arctic. In the Strait of Georgia, CSS *Wm. J. Stewart* continued the Mini-Fix survey, completing the area from Active Pass to Burrard Inlet. Additional control sites were established to carry the work westward in the 1969 season. *Marabell* surveyed Departure Bay, including the Biological Station wharf and the B.C. Ferries wharf. Minor revisory surveys were carried out in Vancouver Harbour and at Northwest Bay, Haddington Island and Seymour Narrows. A survey of Knox Bay and Mayne Passage requested by the Department of National Defence was commenced.

On the northern coast of British Columbia, *Wm. J. Stewart* continued the Mini-Fix surveys in the Chatham Sound area and control surveys were made in Prince Rupert Harbour for the 1969 season's work. The site of the antennae for a new Loran-A station at Gray Point in the Queen Charlotte Islands was fixed at the request of the Department of Transport. *Marabell* completed a survey of Troup Passage and began a survey of Spiller Channel.

A shore party, equipped with a high-speed launch, completed a survey of Stuart Lake in the interior of British Columbia.

The year 1968 was relatively good for ice and weather in the Western Arctic. Hydrographic parties aboard CSS *Richardson* and CCGS *Camsell* concentrated their efforts mainly on Sachs Harbour, Kings Bay, the northwest approaches to Kugmallit Bay, and the river mouth and anchorage at Coppermine. *Camsell* made minor surveys at other western Arctic locations.

Current-meter observations were obtained by CSS *Parizeau* between Parksville and Welcome Pass as the first stage of a study of water circulation in Strait of Georgia, and synoptic temperature-salinity cruises were made in Juan de Fuca and Georgia Straits every five weeks through 1968, as a joint project with the Pacific Oceanographic Group.

An intensive tidal survey was made by shore parties in Georgia and Juan de Fuca Straits during 1968. Twenty-two gauges were operated for a one-year period in addition to the permanent stations in the area. Tide gauges and temperature recorders were maintained in the Gorge and Portage Inlet to assist a water-quality investigation being conducted by the Pacific Oceanographic Group.

The Tidal and Current Section completed the first phase of a study of tidal currents in First Narrows, Vancouver, for the National Harbours Board. The investigation is being made in support of a planned tunnel crossing of the harbour.

Operation of permanent gauge stations on the Canadian West Coast and Western Arctic Coasts was transferred to the Inland Waters Branch offices at Vancouver and Calgary, on April 1, 1968. The Tidal and Current Section has retained responsibility for providing tidal information, and for operating special gauges. New *tsunami*-warning gauges were installed at Tofino and Victoria, in cooperation with the Tides and Water Levels Section from Headquarters. (*Tsunami* is the name given to an extensive and often very destructive ocean wave caused by a submarine earthquake.)

Central Region

All 1968 field operations were shore-based as the Region continued to place the emphasis on mobility and flexibility. Support was provided by one helicopter, which moved between the field parties as required.

A party aboard a new 36-foot survey launch *Verity* started a revisory program; 19 charts in Lake Ontario were examined.

Hydrographers assigned to the Polar Continental Shelf Project completed a LAMBDA-controlled survey of M'Clure Strait and its western approaches and a reconnaissance survey of Baumann Fiord. On both surveys, soundings were made through the ice. A ground control survey in the Mackenzie Bay - Beaufort Sea area was made to site the LAMBDA chain in the area for the 1969 season. An intensive study was made of the use of hovercraft as survey vehicles.

Small-craft charting of the Trent-Severn Waterway and the coastal route in Georgian Bay from Port Severn to Parry Sound was completed. The eastern and western approaches to Owen Channel at the entrance to Georgian Bay were surveyed, thus completing the first modern survey of this dangerous area.

The Lake of the Woods survey was continued and the hydrographers obtained sufficient data for a second chart in the new series of charts of this popular lake.

Eight survey projects were carried out in the St. Lawrence River and Seaway areas, with the major effort being made on a re-survey of the river in the Batiscan area. Half of this latter job was completed. This party field-tested much of the newly developed

survey equipment and used the modified Hydrodist positioning system extensively in the Batiscan area. On the Upper Ottawa River, the surveys were completed upstream almost to Pembroke.

Field testing of semi-automated methods of processing field data and developments in positioning systems was continued. The electronics group in the Central Region provided valuable support to the survey parties and to the Canada Centre for Inland Waters at Burlington.

Atlantic Region

CSS *Baffin* began the first year of a two-year survey of the eastern portion of the Gulf of St. Lawrence. This is a combined hydrographic-geophysical LAMBDA-positioned survey, and is designed to satisfy the requirements of navigation, mineral resources, fisheries and defence.

Hydrographers aboard CSS *Kapuskasing* made a Hi-Fix-positioned survey off the eastern approaches to Fogo Island.

CSS *Acadia* continued the survey of Sir Charles Hamilton Sound on Newfoundland's northeast coast. A survey of the harbour and approaches at Ile aux Morts, Newfoundland, was made in support of a large fish-processing plant that has been established there.

CSS *Maxwell's* two main projects were a check survey of the eastern portion of the Strait of Canso and a survey of the harbour at Come-by-Chance in Newfoundland in support of the construction of two major oil refineries that will be supplied by tankers drawing up to 84 feet. *Maxwell* also made a survey of a wharf area in Long Harbour in support of a major phosphorus-processing plant and started a survey of Marystown, in Mortier Bay, in support of a ship-building and repair industry.

Hydrographers in the Eastern Arctic aboard CCGS *d'Iberville* surveyed the inner portion of Wakeham Bay in support of a mining development and made a reconnaissance survey of Allen Bay as part of a Department of Transport study to use Allen Bay as an alternative to Resolute Bay during severe ice conditions. On the return voyage, a team of geophysicists joined the ship and a series of geophysical hydrographic traverses were made of the continental shelf and slope from Frobisher Bay to the Strait of Belle Isle.

Chart-revisory surveys were continued in the New Brunswick - Prince Edward Island area aboard CSL *Tudlik*.

The hydrographic-development group at the Atlantic Oceanographic Laboratory had another active year. A detailed evaluation was made of the accuracy of navigation-satellite systems aboard CSS *Baffin* in the Gulf of St. Lawrence and CSS *Hudson* on the Mid-Atlantic Ridge. Four semi-automatic chart scalers developed by the group were used successfully in the field. Other developments in positioning systems were tested, and planning was initiated for the development of data-logging systems.

OCEANOGRAPHY

The oceanographic work of the Branch is designed to provide information on the large variety of marine conditions, which in addition to basic charting may benefit the economy and resource development of Canada.

Its activities range from basic studies on tides, waves and storm surges, (including the modification of these effects by coastal topography) to geological and geophysical studies of the Canadian continental shelves and the adjacent deep oceans. The chemical and physical processes of the sea affecting fisheries, defence and weather modification are also studied.

The major centres of oceanographic research are the Ottawa Headquarters region and the Bedford Institute at Dartmouth, N.S.

The Ottawa Headquarters group concentrates on special studies of national service and implication. It supports a national data centre—The Canadian Oceanographic Data Centre—and has specialized in tidal and water-level problems and on wave climate. A strong Systems Analysis and Programming Section supports these specialized activities.

The Systems Analysis and Programming Section has grown considerably in the past year, both in personnel and equipment, and consequently has been able to provide service on a greater scale to the other sections of the Branch as well as other oceanographic agencies.

A five-year wave-climate study was initiated in co-operation with Department of Public Works, Department of Transport, National Research Council and National Harbours Board, with the detailed work and expenditure being borne by Public Works and Energy, Mines and Resources. At the end of this five-year plan the project will become the responsibility of the Department of Energy, Mines and Resources.

The Chief Oceanographer has participated in the preparation of the final reports on pollution in Lakes

Erie and Ontario and the St. Lawrence River in conjunction with other federal government departments, the Ontario Water Resources Commission and the United States government. These reports will be published in 1969 under the auspices of the International Joint Commission.

Pacific Region

Weathership program. The program of oceanographic observations from the Canadian weatherships was initiated in 1952 with BT observations twice daily at Station P and bi-hourly en route to and from Station P. In August 1956, the program was enlarged to include the systematic oceanographic observations at Station P from one ship. This program continued regularly on each cruise of one ship until 1968, when it was expanded to the two weatherships *Vancouver* and *Quadra.*

The weathership studies represent the longest continuous record of time-series observations for the deep ocean anywhere in the world. It has provided basic information on the spectrum of oceanographic variability, decay of the seasonal halocline, vertical mixing and diffusion processes and internal waves.

Steps are being initiated now to add a buoy program to the weathership operations in cooperation with a number of Canadian and U.S. agencies.

Atlantic Region

Air-sea-interaction studies have been continued during the year. The stable platform, which was developed to help in measuring the energy exchange across the air-sea interface, was moored near the approaches to Halifax Harbour from April to October, 1968. Many excellent measurements of wind stress were obtained and it is expected that others, at higher wind speeds, will be obtained as a result of the re-mooring of the platform in the spring of 1969.

Sea ice is an increasingly important factor in the development of the national economy and it is therefore imperative that we have a better understanding of its formation, behaviour, and properties. Such studies have been under way for some time by the frozen-sea research group, which had a particularly successful field season in 1968. It was able to extract a six-ton block of ice from Cambridge Bay, Victoria Island, N.W.T., which, after detailed examination, provided new information of brine-drainage channels, salt rejection, and the dynamics of brine-induced convection in the water beneath the ice. A beginning was made on a major study of ice behaviour in the Gulf of St. Lawrence in cooperation with McGill University and the Department of Transport.

As a result of continuing studies of ocean circulation, the importance of time-dependent processes, the problems of variability, in the oceans has become much clearer. The conviction is growing that the key to the quantitative description of important physical processes in the sea not presently understood lies in the development of practical methods of observing and analyzing time-dependent phenomena, guided by meaningful theoretical models. Considerable progress was made in this facet of the program during the past year.

Although the applied-oceanography section is relatively young as a unit (three years), it has already doubled in size and its services are constantly in demand. It has become the central authority in the Institute for the development and evaluation of moored oceanographic buoy systems and is a prime user of these for the maintenance of standard oceanographic stations and for current measurements in the surrounding waters. The section was also called upon to help in the solution of a number of specific problems; for instance two pollution problems, one in Pictou Harbour and one in the Strait of Canso.

The highlight of the past year's efforts of the marine-geophysics group was the cruise "Hudson Geotraverse". The purpose of the cruise was to study the structure beneath the Atlantic in a one-degree-wide strip (45°-46°) from Cape Breton Island to the eastern flank of the Mid-Atlantic Ridge, via the Tail of the Bank. The traverse crossed most of the major oceanic provinces, and it is believed that the aim of the cruise—a better understanding of the origin and processes in the formation of the deep-ocean basins—was achieved. In addition, many important gravity and magnetic data were obtained on a joint hydrographic-geophysics survey in the Gulf of St. Lawrence.

Of all the disciplines represented in the Atlantic Oceanographic Laboratory (AOL), that of marine geology probably faces the greatest challenge and opportunity on the Canadian Arctic and Atlantic Continental Shelves. This immense area (about one million square miles) is as yet only superficially investigated but undoubtedly contains resources of great potential value. Reconnaissance investigations over the area, involving the techniques of sedimentology, micropaleontology, and geochemistry, begun some time ago, have been continued and expanded in 1968. In partic-

ular, there has been a shift to the more intensive study of specific areas, such as the Scotian Shelf, the Grand Banks, and the Labrador Coast, partly in response to the recent upsurge of interest in petroleum exploration of the Atlantic Continental Shelf.

In addition to cooperative ventures between sections within AOL, there has been considerable cooperation between AOL and the Fisheries Research Board unit at the Bedford Institute, the Marine Ecology Laboratory. Such studies as a complete physical and chemical oceanographic and biological investigation of St. Margaret's Bay, near Dartmouth, and the two pollution problems previously mentioned, are examples. There was also a large-scale cooperative cruise to the Caribbean that involved, in addition, scientists from universities, government, and industry in other parts of Canada, the United States, the United Kingdom and Venezuela. The usual good working relations with the Institute of Oceanography of Dalhousie University and other research establishments in the area were maintained and strengthened.

The Meteorological Research Section is primarily engaged in the design of instruments for measuring various parameters in or obtaining samples from the marine environment. This is usually, although not always, done at the request of other AOL staff who need the data for their research. Thus, the personnel of the section works on many different projects each year on a completely interdisciplinary basis. Some examples of completed equipment developed by the section are: the Bedford Institute Oceanographic Data Logging System (BIODAL), a multi-recorder precision sounding system, and an automatic flat-bed plotting table. Some continuing projects are: a radio-controlled launch, an automatic bathythermograph, an oblique echo-sounder, and a data-processing system.

Policy and Planning Branch

The Policy and Planning Branch advises on and recommends national undertakings concerning water, air, and other renewable resources. It helps to coordinate federal, interdepartmental, federal-provincial and international activities in use and study of air and water, and advises on the socioeconomic impact of such activities.

The Branch consists of three divisions and an administration. The library of the Water Group is also attached to the Branch.

POLICY ADVISORY, COORDINATION AND ADMINISTRATION DIVISION

This Division conducts and coordinates current and proposed studies for the development and management of water and other natural resources, and administers federal-provincial agreements in those fields.

During 1968-69 the Division reviewed federal water policies and activities as a basis for drafting new water legislation designed to initiate and encourage federal and federal-provincial activities for the comprehensive development and management of Canada's major river systems. Preparation for the new legislation included consultations with federal and provincial government officials as well as with ecologists, lawyers, engineers and economists. The proposed legislation places particular emphasis on cooperative federal-provincial activities for water-quality control and pollution abatement.

The Water Policy Advisory Section provides the secretariat for the Interim Interdepartmental Committee on Water. The committee, chaired by a senior official of the Department, reviews all federal water policies. Sub-committees develop proposals for regional water activities in the Atlantic Region, the Prairie Provinces and British Columbia. On the national scene, the sub-committee on water quality with the assistance of the secretariat carried out an extensive background study on federal policies and programs respecting water pollution in Canada in support of a coordinated interdepartmental approach to this problem. A preliminary national contingency plan for dealing with disaster pollution is now being considered. *Ad hoc* committees undertook special tasks, such as the preparation for federal action under an International Joint Commission reference concerning connecting channels in the Great Lakes.

Recognizing the growing pollution of the natural environment and the intimate interrelationship of air, water and soil quality the Division initiated studies of the level and extent of environmental pollution, the

cost of pollution control, jurisdictional and administrative issues, and the socioeconomic and ecological factors that must be considered. Much of the preliminary work will be done by consultants.

The Division is responsible for liaison between federal agencies and the Canadian Council of Resource Ministers. The latter is composed of eleven ministers—one from each province, together with the Minister of Energy, Mines and Resources representing the federal government. The Council is advised and assisted by a coordinating committee, for which the federal representative is an official of the Department. Among the projects undertaken for the Council was the preparation of papers for and participation in a workshop seminar on water resources in the fall of 1968. The seminar proved very successful in providing ministers and their aides with an opportunity to study and discuss basic issues in water policy and planning. The Council has been urged to sponsor a series of regional seminars.

The secretariat of the Interdepartmental Committee on Resources is furnished by the Division, and recently provided the Canadian Council of Resource Ministers with an updated inventory of federal-provincial cooperative resource-development agreements. The material, compiled in conjunction with similar information provided by the provinces, was to be published during 1969.

The National Advisory Committee on Water Resources Research, established in 1967, completed its first full year of operations. It consists of experts from both federal and provincial agencies, universities and private industry. The committee has two sub-committees, one on social science and one on natural science. Chaired by an official of the Department, the committee has three functions: to advise the Minister on needs and priorities for water-resources research in Canada; to help coordinate such research; and to review and make recommendations on applications for grants in aid of water research dispensed by government. In 1968-69 these grants amounted to $283,038; social sciences $93,950, and natural sciences $189,088. The committee's secretariat is provided by the Division.

WATER MANAGEMENT RESEARCH GROUP (WMRG) OF THE ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD)

The Water Management Research Group (WMRG) was formed in June 1967 by the Committee for Research Cooperation of the OECD; Canada is one of the 18 member countries. The Assistant Deputy Minister (Water) is the Canadian Delegate to the WMRG, with secretariat services supplied by the Policy and Planning Branch. The Director of the Branch has attended the WMRG meetings for or with the Canadian Delegate.

The purpose of the committee is to exchange information on water-management research in member countries; to identify research needs arising from developing national management in member countries; and to propose ways and means of cooperation in the required research, consistent with existing national programs, so as to result in maximum benefit to the member countries.

In 1968-69 three meetings of the WMRG were held—in Reading, Essen and Paris. The WMRG also sponsored several experts meetings; Canadian experts attended the meetings on documentation and information in the water field and on lakes and reservoirs (eutrophication).

PLANNING DIVISION

Through the Interdepartmental Committee on Water this Division undertakes and coordinates water-planning studies in cooperation with other federal departments, with provincial agencies, or through consultants. Such studies include the economic, legal, social, administrative, financial and physical aspects of regional and national water planning and projects. The Division has three sections: regional studies, general studies, and resources data.

The Canada-British Columbia Agreement for studies and flood control in the Lower Fraser Valley was signed on May 24, 1968. Staff from the Planning Division are on the Joint Program Committee directing studies relating to the reduction of flood damage. The agreement provides for an expenditure of a maximum of $18,000,000 by Canada and for a similar expenditure by British Columbia over ten years.

Officials have discussed an agreement for a comprehensive basin study of the Okanagan Basin with officials of the Province of British Columbia. It is expected that the study will seek to solve the problems of pollution-induced eutrophication and of future water demands. The study, involving provincial agencies and several federal departments, is being coordinated by the Planning Division.

In the Prairies, an *ad hoc* committee composed of officials from Canada, Saskatchewan and Manitoba discussed a proposed study of the Qu'Appelle River Basin in Southern Saskatchewan. Discussions on the scope of the study and financial arrangements are continuing.

Further progress has been made on the Northern Ontario Water Resources Study. A preliminary report on the existing economy and patterns of water use in the northern watersheds is being prepared in cooperation with Ontario. Part of the report will be an atlas depicting the present distribution of economic activity in five major river basins of Northern Ontario.

The Canada-Ontario Committee on the Canada Water Conservation Assistance Act Programs has continued with the preparation of a *Manual of Standards, Guidelines and Procedures for Water Resources Planning.* The Planning Division's contribution described the purpose, principles and methods of economic evaluation of water-resource activities. The manual was expected to be completed by the summer of 1969.

Division staff continued to provide advice and assistance to the Atlantic Development Board in connection with the first stage of a comprehensive study of the water resources of the Atlantic Region by consultants. Direction for the study comes from a federal-provincial supervisory committee made up of officials from several federal agencies and the four Atlantic Provinces. The head of the Atlantic regional unit is secretary to the federal-provincial supervisory committee.

Four study reports covering, (a) the supply of and demand for water in the Maritime Provinces, (b) the supply of and demand for water in Newfoundland and Labrador, (c) the legal framework, and (d) the administrative framework, are currently being reviewed prior to final submissions. It is expected that the reports, when completed, will comprise some 50 volumes of information and analyses of water problems in the Atlantic Provinces.

Officers of the Division have met with officials of the Province of New Brunswick to negotiate an agreement for comprehensive planning and development of the water resources of the Saint John and St. Croix River Basins.

The newly established Resources Data Section has been setting up a base for the collection, categorization, storage and retrieval of information to support the activities of the Division and Branch.

The General Studies Section has continued to help the regional units and divisions with economic analysis and project evaluation and other special assignments.

RESOURCES RESEARCH CENTRE

The Resources Research Centre carries out basic research on the best use of national resources through integration of existing knowledge in the economic, sociological and technological fields. It also advises other divisions and branches and administers grants in aid of geographical research in Canadian universities.

The Centre has continued to be concerned with a wide range of problems of resource management and utilization. Much of this activity has been concentrated in Northern Ontario and the Atlantic Provinces. Canada Land Inventory land-use mapping of western Newfoundland continued on behalf of ARDA. It will be completed when air photos become available for the small remaining area. Studies continued on the regional factors affecting resource utilization in Newfoundland, particularly marine resources. In Prince Edward Island the Centre has taken a leading part in a major program of rural management studies. This program involves a large number of federal and provincial agencies and is concentrated in land reorganization and improvement. Similar work went on in Nova Scotia and plans started for an extension to New Brunswick. Other studies include an examination of the social and economic implications of ice distribution and movement in the Northumberland Strait.

In the central region the Centre has been primarily engaged in a study of resources and economic activity in those Ontario watersheds that drain to Hudson and James bays. This study is almost complete. Farther west, plans were made for participation by the Centre in the comprehensive study of the water resources of the Okanagan Basin which is envisaged by the federal and British Columbia governments.

Lastly, the Centre has continued its long-term study of social and economic variations across Canada. Plans are being made for extensive research at the Canada Centre for Inland Waters, Burlington, Ontario, and the development of scioeconomic studies of marine resources.

Research into new resource-management techniques, such as air-photo interpretation of flood plains and simulation models for water-quality management and other purposes, is in progress.

Inland Waters Branch

The Inland Waters Branch provides, at the federal level, services in natural sciences and engineering needed for optimum management of Canada's water resources. It produces scientific or engineering data, research results, or engineering studies, appraisals or advice.

One of the Branch's major objectives is the collection and dissemination of information on water quantity and quality throughout Canada. This is being achieved through networks of observational and sampling stations on Canadian rivers, lakes, aquifers, glaciers and snow courses. Emphasis is placed on making the collected data readily accessible in the most usable form.

Also of major importance is the Branch's responsibility for providing to the Government of Canada advice on technical aspects of managing interprovincial and international waters. This takes the form of technical studies in support of international and federal-provincial programs and agreements relating to fresh water.

To ensure that Canada's water resources are being used wisely for the benefit of present and future generations, new concepts have to be developed and new knowledge acquired of the behaviour and occurrence of water in the hydrologic cycle. Standards and procedures for improved regulation and use of the country's fresh-water resources will have to be found, and methods for predicting the response of lakes and rivers to pollution as a basis for economic pollution control must be developed. Liaison with other government agencies, universities and industries must be fostered both nationally and internationally for exchanging knowledge in the water field. These are the chief objectives of the Inland Waters Branch in its endeavour to provide the Government of Canada with the information essential for the development and application of an effective national water policy.

The Branch undertakes a prolific publications program in order to make its scientific and engineering data and studies available to the scientific community. During the past year more than 50 scientific or technical publications or brochures were published by the Branch, and a number of papers were published in scientific journals.

The following sections briefly describe the role of the Inland Waters Branch in the activities of the Canada Centre for Inland Waters as well as the activities of the various Branch units that are not associated with the Centre.

CANADA CENTRE FOR INLAND WATERS

The Canada Centre was established in 1967 at Burlington, Ontario, as a new federal centre for water research. The Department of Energy, Mines and Resources, mainly through its Inland Waters Branch, but assisted by the Marine Sciences Branch and the Policy and Planning Branch, coordinates the activities at the Centre in collaboration with the Fisheries Research Board, the Department of National Health and Welfare, and the Association of Universities and Colleges of Canada.

A significant part of the Centre's work in 1968 was the preparation of major sections of the International Joint Commission report in connection with the pollution reference on Lakes Erie and Ontario and the international St. Lawrence River. This report, in three volumes, is being prepared in collaboration with the Ontario Water Resources Commission and United States federal and state agencies. The report will summarize available knowledge of pollution of the two lakes and the upper St. Lawrence River and will make recommendations for remedial measures based on present information. However, in the course of preparing portions of the report, significant gaps in our knowledge of the lakes became evident and the scientific operations of the Centre are being designed to deal with the more important unsolved problems.

During the year the Centre coordinated an extensive field program involving a number of interdisciplinary surveys on the Great Lakes. These surveys, along with the data collected from fixed moorings of instruments in the lakes and other studies, are designed to develop a body of information from which it will be possible to predict diffusion and movements of pollutants; determine temperature distributions and the availability of light for biological productivity; assist in assessing water budgets; determine the trends in chemical composition of lake waters under the impact of natural and man-made processes; assess extent and nature of water-level fluctuations; assess the problems of erosion and sedimentation; determine the role of sediments in the cycling of pollutants in lakes; determine the degree to which the ageing process or

"eutrophication" has progressed in the various parts of the Great Lakes; and assess the impact of pollutants on the lake environment. Research on subjects such as these will provide the basis for determining means by which pollution abatement and other water-management measures may be designed to take advantage of, and work with rather than against, natural lake processes. This will ensure efficient use of the large sums of money which are being spent on pollution abatement, water-level control, shore-erosion prevention, and construction of lake structures.

The Centre is presently housed in a 25,000-square-foot trailer complex and in an assortment of temporary buildings, which provide housing for laboratories, stores, workshops and a library, and office space for administration, scientific study, data processing and drafting. During the past year the development of a permanent site included the completion of land reclamation and construction of sewage, water-supply and electric-power facilities. Marine facilities, including a breakwater and berthing for major vessels and launches, were installed and are in use. Contracts have been awarded for foundations for the boiler plant, the research-and-development building and the workshop, launch-repair and warehouse building; these buildings are scheduled for completion during the summer of 1970. The main building containing laboratories, mechanical facilities and ancillary services, and a hydraulics building containing instrument-calibration and research facilities, are scheduled for completion in a phased program from 1971 to 1973. A water and wastewater-treatment research laboratory is also to be constructed in which pilot-scale studies will be undertaken to permit the development of plant-scale pollution control and water-treatment processes.

WATER SURVEY OF CANADA

The Water Survey of Canada conducts a systematic survey of streamflow, water levels and sediment transport throughout Canada and publishes the results annually. In addition it carries out snow and glacier surveys and water-power surveys, the latter mainly in areas of federal jurisdiction. The Water Survey has also been assigned the task of expanding its survey network to collect field data on behalf of other departmental agencies responsible for the collection and interpretation of data on water quality, groundwater, snow, ice, and tides. During danger periods on rivers subject to floods, a flood-warning service is maintained in cooperation with the provinces concerned. Although all of these activities are designed to meet the requirements of the federal government, an increasing portion of the total effort is aimed at satisfying needs of the provinces.

The Water Survey of Canada and its predecessors have collected and published basic streamflow and water-level data on a national basis for more than half a century; the sediment survey has been in operation since 1961. These surveys are being expanded steadily and at present are conducted from 30 district and field offices extending across Canada. Planned expansion in 1969 will see district offices established at Regina and Fort Smith to provide closer liaison with agencies in Saskatchewan and the Northwest Territories, respectively.

In 1964, the Quebec Department of Natural Resources assumed responsibility for the collection of hydrometric data for most rivers in Quebec; however, collection of data for a number of navigable and international streams in Quebec remains the responsibility of the Water Survey.

During the year under review some 60 stations were added to the Water Survey's gauging network, bringing to approximately 2,250 the total number of streamflow and water-level stations. Sediment data are gathered at 82 of these stations, an increase of five stations during the year. The above total also includes 130 water-level stations operated in the field for the Tides and Water Levels Section of the Marine Sciences Branch; most of these stations are located in the Great Lakes-St. Lawrence River system. The Water Survey also participates in the collection of hydrologic data for some 40 research watersheds established for the International Hydrological Decade.

About mid-year, hydrometric-network planning, aimed at providing a sound basis for further network expansion, was greatly intensified by enlisting the services of two consultants for planning the British Columbia and Ontario networks. By agreement with the Department of Indian Affairs and Northern Development (IAND), the Water Survey of Canada carries out the hydrometric survey in the Yukon and Northwest Territories; the Water Survey also collaborates with IAND in assessing the water resources in these areas.

Intensive sediment surveys on the lower Fraser River continued so as to provide a sound basis for the maintenance and improvement of the navigation channels in the river. Similar work on the South Saskatche-

wan River is under way to determine the effect of sediment deposition in Lake Diefenbaker and degradation in the river downstream of the dam. A terrestrial photogrammetric study to determine the extent of shoreline erosion of Lake Diefenbaker was also undertaken.

Automatic data-processing was initiated in 1966 when two major projects were undertaken—the storing of historical hydrometric data on magnetic tape, and the developing of automated procedures for the computation of current hydrometric data. Approximately 31,000 station-years of record, representing all historical daily-discharge data to 1967 inclusive, were key-punched and converted to magnetic tape. Also, special equipment for digitizing charts has been purchased for the development of automated streamflow computations. These systems are now partly operational and will be fully operational in all districts across Canada early in 1970.

Engineers of the Water Survey of Canada are members of, or participate in, the activities of some 20 engineering boards, committees and special studies in connection with various aspects of national, international and interprovincial water problems. These responsibilities include major streamflow measurements on the interconnecting channels of the Great Lakes, on Northern Ontario rivers and on the Nelson River.

HYDROLOGIC SCIENCES DIVISION

The Hydrologic Sciences Division undertakes research into the physical processes governing the behaviour of water in the hydrologic cycle to improve methods of water management. In addition, it takes part in such international research as the International Hydrological Decade and the International Field Year on the Great Lakes, and enters into joint research with universities, provincial authorities and other government departments and agencies in order to increase the understanding of the basic processes of the hydrologic cycle, with particular emphasis on Canadian situations and applications.

The Division consists of three operational subdivisions—Glaciology, Groundwater and Water Science. The Division also provides administrative services required by the Secretariat of the Canadian National Committee of the International Hydrological Decade. The preliminary design of a hydraulics laboratory to study the behaviour of moving water under environmental conditions, to be situated at the Canada Centre for Inland Waters at Burlington, has been completed. Although it is expected that it will eventually result in the formation of a separate Division, the hydraulic nucleus is being formed within the Hydrologic Sciences Division.

Glaciology Subdivision

The annual mass-balance data for representative glacier basins in western Canada and the eastern Arctic together with energy-balance and water-discharge data, continued to be collected. Each eastern Canadian basin showed a net positive mass balance. In addition, photogrammetric measurements are being made annually in selected basins in order to determine glacier movement.

A project to develop a hydrologic model of a glacier basin has been initiated. This model will be applied to meltwater from ice and snow in the upper reaches of the North Saskatchewan River and should lead to a method of predicting the contribution to runoff from snow and ice in glacier basins.

A Glacier Inventory Section was formed within the Subdivision to complete ice and permanent-snow inventories in Canada. In order to obtain an inventory of water stored as ice in temperate glaciers, an instrument to measure the thickness of temperate glaciers has been developed by the Glaciology and Water Science Subdivisions, through contract with industrial firms.

The continuous small discharge of water from Summit Lake, B.C., through a channel beneath the Salmon Glacier was confirmed through the use of a dye-tracer experiment. This lake periodically empties in a catastrophic manner causing flooding in the valley below. A project has been initiated to discover the mechanism that triggers this phenomenon.

An Ice Science Section to investigate the fundamental properties of ice as related to ice deformation and movement has been established and X-ray apparatus for studying dislocations in ice has been assembled. Complementary studies of the stress-strain relationship of single-crystal and polycrystal ice are in progress and the effect of impurities on the strength of ice is being investigated.

A series of seven maps showing the glacier distribution in the Arctic regions on a scale of 1:1,000,000 was completed during the year. A project involving the Subdivision and the National Parks Branch, Department of Indian Affairs and Northern Development, will produce, in shaded relief, a map of the Peyto Glacier in

Alberta in combination with an illustrated text comprising historical, geographical, geological and other information of interest to tourists.

Groundwater Subdivision

The demand for information pertaining to the management of water resources along the eastern seaboard has led to the establishment within the Groundwater Subdivision of a Maritime Research Section. The Section has been empowered to obtain information on seawater intrusion into coastal aquifers, to develop hydrochemical pumping-test techniques for coastal well fields and to develop geophysical methods to study groundwater flow in fractured rocks.

In preparation for the International Field Year on the Great Lakes (1971-72), considerable effort is being made to study groundwater flow in the Lake Ontario Basin. This study includes the development of a parametric model of the Northern Lake Ontario Basin, an assessment of the groundwater inflow into Lake Ontario and the construction of hydrogeological maps of the basin. Data, which are being provided by the Ontario Water Resources Commission through a cooperative arrangement, will be processed through the groundwater-data-storage system associated with the Groundwater Observation Well Network (GOWN) in order to provide the required maps. Retrieval programs are being written by members of the Hydrologic Sciences Division. The study involves close working relationships with agencies in the United States. A number of provincial governments have shown interest in this project because, in due course, GOWN will be capable of providing the basis for maps showing such features as bedrock topography, aquifer delineation, etc., based on data obtained from local wells.

As part of the program to obtain an inventory of Canada's water resources, a method has been developed, using standard maps and a pencil follower, to compute the areas of lakes greater than 100 square kilometres. The information is stored in such a manner that it can be augmented with depth measurements when available and updated as necessary.

In the Ottawa Valley region, a project to trace buried river channels by hydrochemical techniques has been initiated and approximately 1,800 wells have been tested between Ottawa and Rigaud. Apart from hydrogeological interest, the data from these samplings have proved to be of considerable interest to the Ontario Department of Highways in connection with highway construction plans.

The program to develop computer models of groundwater flow systems has been further extended to include a number of boundary conditions commonly encountered in nature. This program leads to the determination of flow systems based on the physical properties of the environment.

Water Science Subdivision

The Water Science Subdivision seeks the basic physical and chemical knowledge that will be required for the effective and economic use of Canada's water resources.

Although little is known about the structure of water and aqueous solutions, it influences much of the behaviour of water, and a better understanding of the structure is necessary for the future development of effective water-treatment methods. Some research projects currently undertaken in this Subdivision are therefore concerned with the properties of solutions of halides, especially chlorides, which are pollutants produced by the chlor-alkali industry and from municipal street wash in winter; also under study are the structural effects of phosphates and nitrates, compounds known to be involved in the eutrophication of natural water bodies. By eutrophication is meant the increase in nutrients, particularly phosphates and nitrates, that stimulate the excessive growth of plant and animal life, whose decay depletes the water of oxygen. The amount of dissolved oxygen can therefore be used to indicate the "health" of natural waters; for this reason the diffusion of oxygen in water and its rate of replenishment through the air-water surface are under study.

Other projects relate to understanding the form in which toxic metallic compounds may exist in natural water bodies, and the manner in which pollutants can be removed from solution by decomposition on the surface of naturally occurring minerals. A small instrumentation group to serve the needs of the Division and to undertake special instrumentation projects has also been established.

International Hydrological Decade Secretariat

The Secretariat's duties are guided by the 26-member Canadian National Committee which coordinates the country-wide scientific investigation and assessment of water resources under the International Hydrological Decade.

In addition to coordinating the studies and organizing the annual meeting of the Canadian National

Committee, the Secretariat organized an annual hydrology course, two workshop seminars, a visiting lecture tour, met Canada's international IHD commitments and provided assistance to provincial and university agencies involved in holding seminars and workshops in hydrology. It also published annual progress reports on the Canadian IHD program, the results of seminars, the results of surveys and a general-interest *News Bulletin.*

GREAT LAKES DIVISION

The Great Lakes Division seeks to provide the knowledge and understanding of the chemical, physical and sedimentological behaviour of Canadian lakes needed for optimum management of the lakes. This task encompasses all Canadian lakes, but the emphasis at present is on the Laurentian Great Lakes because of their economic importance.

To carry out its functions, the Division conducts applied research and collects scientific data, and engages in limnological instrument design, development and evaluation, augmented by a modest amount of basic research. Also, it encourages and promotes Great Lakes research in Canada and plays a leading role in coordinating research and data collection with its counterparts in the United States. Scientific support as well as administrative and technical services are provided to the various divisions and agencies at the Canada Centre for Inland Waters.

Physical Limnology

During the first part of 1968, a major effort was directed to examining circulation and thermal and turbidity features in Lakes Ontario and Erie, and reporting on these to the International Joint Commission on pollution of these lakes. Later in the year, the emphasis was shifted to studies of lake processes, with the aim of improving knowledge of lakes and devising techniques for predicting lake phenomena. The study of lake processes included water movement, diffusion, and remote sensing as well as air-lake studies and water-level studies. Progress was made in the mathematical representation of the physical processes important in lake circulation, and work was begun on the preparation of an atlas of Great Lakes data.

During the year, attention was turned to lakes other than the Great Lakes. Although relatively small at present, this effort is expected to increase over the next few years.

Preparations for 1969 studies have centred on meteorological, physical, chemical and geological processes in western Lake Ontario. Involving two 7-week periods of concentrated measurements, these studies are feasibility investigations prior to the International Field Year on the Great Lakes in 1971-72.

Limnogeology

Early in 1968, the Limnogeology Section was transferred from Ottawa to join the rest of the Division at Burlington.

The 1968 studies were designed as the first part of a continuing series. They fall into the following categories: sedimentology, stratigraphy, paleoecology, inorganic and organic geochemistry. The sedimentology section carried on sampling and underwater studies in Canadian nearshore areas and in the western end of Lake Ontario, grid sampling in the Niagara-on-the-Lake area and in Georgian Bay, and a preliminary assessment of sedimentation in Lake Diefenbaker, the newly formed reservoir of the South Saskatchewan River project. The stratigraphy section continued long-term projects of coring and bottom sampling in Lakes Erie and Ontario. In the paleoecology section, the environmental relationships of chironomidae, small organisms found in the Great Lakes, are under study; being extremely sensitive to eutrophication, chironomid forms will provide delicate indicators of the paleo-environment. The geochemistry and sedimentological studies are showing that Lake Ontario is composed of four major depositional basins separated by various sills or divides whose presence would seem to affect lake productivity. From these, and various smaller research projects and equipment trials, a wealth of information is being harvested.

Chemical Limnology

The Chemical Limnology Section is responsible for the evaluation of the chemical balance of the Great Lakes with respect to nutrients as well as organic and inorganic materials. Study of the 1968 monitor-cruise data for Lakes Erie and Ontario indicates that more sampling stations and more frequent sampling and analyzing for total phosphorus and total nitrogen are needed in order to improve our understanding of the nutrient budgets of the lakes. Accordingly, plans for 1969 called for an intensive year-round chemical monitoring of Lake Ontario, with special emphasis on these nutrients.

Rain monitoring was expected to begin in mid-1969 to determine the portion of the nutrient budget of the Great Lakes supplied by rainfall.

A variety of salt solutions are being studied to determine the deviation from ideal behaviour of salts in aqueous solution. The fundamental physical and chemical properties of aqueous solutions must be known before we can completely understand the behaviour of natural waters.

In the engineering area, significant advance was made in the preparation of current-meter data for computer analysis, and a fast-response, non-wetting wave probe was developed for detailed analysis of small-scale waves in connection with air-water interaction research. Numerous other engineering problems tackled include developing improved structures to house instrument systems, automating the collection and translation of data, developing dye-diffusion methods and calibrating equipment.

In technical operations, CSS *Limnos* and the charter vessel *Theron* were used during the Great Lakes studies in 1968. Both ships were operated in Lakes Erie and Ontario, but the *Theron* also carried out a monitor cruise on Lakes Huron and Superior. The chartered tug *Lac Erie* and seven smaller launches were also used in Great Lakes studies during 1968.

The computer and data personnel continued to summarize data, and contributed considerable support in abstracting and plotting data, computer programming and undertaking statistical analyses for the scientific staff.

Appointment of a full-time librarian in 1968 permitted development of library services for both the Great Lakes Division and other components of the Canada Centre.

ENGINEERING DIVISION

The Division conducts field and office engineering investigations and studies leading to reports and recommendations on the development of water resources. It establishes ranges of engineering costs and estimates benefits relative to direct engineering considerations such as hydro-electric power generation, and water supply for domestic, industrial, irrigation or other purposes. The Division provides technical advice on water matters to various federal and provincial departments and agencies; examines and reviews proposals for water conservation and control, including hydrology, hydraulic and structural design features, and comparison of project benefits and costs; maintains continuing inspection and review of water-conservation and control projects to which Canada is contributing financially; undertakes negotiations with respect to federal participation in water projects and participates in federal-provincial and international boards and committees established for water investigation, development, control and regulation.

The Division helps to plan water policies and development by taking part in inter-disciplinary task forces.

To cope with its manifold tasks, the Division has grouped its country-wide investigations and studies into four regional sections—Atlantic, Central, Western and Pacific. Three service sections provide services in engineering hydrology, field investigations, and project design and appraisal to the regional components. Except where specifically noted, the Division's activities are located in Ottawa.

Engineering Hydrology Section

In 1968, the water levels of the Peace River, Lake Athabasca and the Mackenzie River were well below normal, causing difficulty to water consumers and navigation. This difficulty was attributed to relatively low natural runoff in the Mackenzie basin in the spring and summer of 1968 and to the holding back of water in the new Peace River reservoir, which began filling in December 1967. The Division carried out calculations to estimate the effect on downstream levels and flows from the filling of the reservoir. The first generating units at the dam were brought into service in 1968, thereby releasing water from storage. It is evident, therefore, that future effects of storage of water in the reservoir should not be as severe as in 1968.

The Section continued studies of flood flows in Nova Scotia and Ontario and updated studies of the total surface-water supply in Ontario. Technical advice was provided to the Atlantic Development Board in connection with the Board's study of water resources of the Atlantic Provinces.

Field Investigations Section

The Division completed the third year of field investigations and engineering-feasibility and cost studies of proposals for water-resource development on four major river basins in Northern Ontario. Storage, diversion and power sites were located, but the preliminary design and costing of structures for alternative

schemes are continuing, and reports on water yield, power potential, cost and physical benefits for alternative development possibilities are in preparation.

Project Design and Appraisal Section

The Canada Water Conservation Assistance Act empowers the Government of Canada to provide financial assistance to the provinces in the construction of major works for the conservation and/or control of water. During the year, the Division's activities under the Act were concentrated on conservation and flood-control projects for the Upper Thames Conservation Authority and the Halton Region Conservation Authority, both in Ontario, and on projects in North and West Vancouver and Alberni, in British Columbia. In Manitoba, similar service was provided under ad hoc agreements with respect to construction of the Red River Floodway, which was virtually completed during the year, and construction of flood-control dykes around several towns in the Red River Valley.

The Canada-Ontario Committee on Canadian Water Conservation Assistance Act Programs, established during 1967, made substantial progress towards the completion of a manual of standards and procedures for planning water management in Ontario.

Atlantic Region Section

The study of the feasibility of developing tidal power in the Bay of Fundy continued during the year. The Engineering Division provides back-up support to the Atlantic Tidal Power Programming Board, which is carrying out the study under an agreement between the Governments of Canada, Nova Scotia and New Brunswick. An engineer of the Division acts as secretary to the Board and to the Board's associated Engineering and Management Committee.

The first phase consisted of a field program and preliminary engineering studies to determine the best arrangements of dams and related structures for tidal power plants in the Bay of Fundy. During the year, work progressed on the second phase which includes analyses of the power potential and preliminary marketing and transmission studies, as well as civil-engineering studies of constructiom methods to determine the most economical scheme of development.

Pacific Region Section

During the year, the Division's responsibilities in the Vancouver area increased, and a Pacific Regional Office was established to carry out the functions of the Division in British Columbia and in the Yukon Territory.

The Regional Office participates in the ten-year federal-provincial Fraser River flood-control program which was authorized in 1968. The regional engineer serves on the Fraser River Joint Program Committee and acts as Chairman or Vice-Chairman in alternate years. The Division cooperated with provincial-government engineers in studies to develop design criteria for dykes, river-bank stabilization and internal-drainage works in the Lower Fraser Valley, and also provided engineering review of the Alberni flood-control project initiated by the province under the Canada Water Conservation Assistance Act.

Engineering support is provided to the Chairman of the Canadian Section, International Columbia River Treaty Permanent Engineering Board, and the regional engineer serves the Canadian Section as secretary and as alternate member to the chairman. The Division analyzed flood control and power operations, prepared reports on implementation of the treaty and on operation of the treaty storages, and reviewed technical reports and special operating programs prepared by the power entities. Engineering support on matters of a federal-provincial nature that come within the scope of the treaty was also provided.

Central Region Section

The Division provides advice on the regulation and control of the waters of the Great Lakes - St. Lawrence system, and an office is maintained at Cornwall from which the regulation of Lake Ontario is supervised by Division members representing the International St. Lawrence River Board of Control under the aegis of the International Joint Commission. The Division also provides technical advice to several other boards established by the Commission, including the International Lake Superior Board of Control which is responsible for regulating the outflows of Lake Superior, the International Niagara Board of Control, the American Falls International Board and the International Great Lakes Levels Board. The latter board, under a reference to the International Joint Commission, is conducting a study to determine the feasibility of further regulating any or all of the Great Lakes, and the Division is making a major contribution to this study.

The Division also participates in the coordination of physical data through membership in several subcommittees of the International Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, a joint Canada-U.S. organization. As part of its contribution to the International Hydrologic Decade, the Division holds membership on the Steering Committee for the International Field Year on the Great Lakes, which is an international observational and research program designed to provide an integrated group of studies aimed at solving the basic problems of hydrology, meteorology, physical limnology and geology of the Lake Ontario basin.

Western Region Section

Work continued on the Saskatchewan-Nelson Basin Study, an examination of the water resources of the Saskatchewan-Nelson Basin, including potential additional supply by diversion or storage. The study is under the direction of the Saskatchewan-Nelson Basin Board. The secretary of the board is an officer of the Division. The Division has accepted a contract from the board to develop a mathematical model to produce synthesized flow sequences at thirteen points throughout the basin. Work on this contract was about half completed at the end of the fiscal year.

WATER QUALITY DIVISION

The Water Quality Division collects, interprets and disseminates data on the quality of fresh water in Canada, conducts applied research in water and wastewater treatment and provides analytical laboratory support for water resources research and field investigation undertaken by the Department, other government agencies, universities and private industry. In applied research, the Division seeks to develop new and improved technology for the best use of Canada's freshwater and for control of water pollution.

Resources and Surveys Subdivision

The Resources and Surveys Subdivision continued to expand the water-quality monitoring and surveillance network which was first set up to collect baseline water-quality data across Canada and to measure the pollutional effects of major municipal, industrial and other wastewaters and surface runoff. Approximately 260 permanent sampling stations were in use during the year, coinciding in almost all cases with gauging stations which are operated by the Water Survey of Canada. Most of the network stations were sampled either bi-weekly or monthly, with samples shipped for analysis either to the Ottawa laboratory or to the regional laboratories at Moncton or Calgary.

Expansion of the network, on the basis of a planned program covering the next several years, was most notable in western and northwestern Canada and in the Atlantic Provinces. This activity, ranging as it does from the Exploits River in Newfoundland to the west-coast rivers of British Columbia and the Mackenzie River in the northwest, points up the magnitude of the water-resource-evaluation task in Canada.

Collaboration with other government departments and provincial agencies and universities on research and experimental river basins throughout Canada, and in support of the Department's commitments to the International Hydrological Decade, was continued, as was the water-quality study of the headwaters of the Saskatchewan River system, in support of the Eastern Slope (Alberta) watershed program. A cooperative geochemical and water-quality study of the Mackenzie River in northwestern Canada was initiated, and the Division participated in the initial planning of a comprehensive water-resources study of the Okanagan Basin, which is under joint consideration by the governments of Canada and British Columbia.

The selection and acquisition of robot monitoring devices received high priority during the year. This is in keeping with the growing requirement for continuous measurement of water quality in locations where industrial or urban discharges may cause variations in water quality not readily determined by manual sampling and analysis on a repetitive basis. One robot was installed in the Columbia River near the International Boundary, on the basis of a joint agreement with Cominco Limited, and a second in the Ottawa River at the City of Ottawa Water Filtration Plant. Preliminary plans were made for housing such units in mobile trailers so that additional robots, to be acquired, can be moved from site to site, as required. As the successful automation of more and more analyses is effected, the use of robots will be expanded.

Monitoring of water quality in streams in the base-metal-mining area of New Brunswick continued. These studies, which are to determine the effects of mine-wastewater discharge on salmon fisheries, are being carried out in cooperation with the New Brunswick Water Authority, the Department of Fisheries, the Fisheries Research Board, and mining companies in the area.

Planning for the computerized storage and retrieval of water-quality data received from the laboratories and from other federal and provincial agencies was completed. Although a national water-quality-data centre may not be fully realized until the planned data-processing facilities at the Canada Centre for Inland Waters are available, current planning is intended to make automated printout of Departmental data available in 1969. Publication of water-quality reports for all of the major watersheds and for groundwaters in many areas will then be undertaken.

Water Pollution Research Subdivision

Although it is intended to expand this Subdivision to provide a broad inter-disciplinary capability in water and wastewater-treatment research, activities in the current year were limited to the participation of the available staff in field and laboratory studies of pollution from base-metal-mining operations. Following field studies, which were undertaken to examine the formation of acid in the waters receiving wastewaters from such mining operations, laboratory studies were begun to determine the kinetics of acid generation and, thereby, to facilitate the preparation of proposals for pilot-scale wastewater-treatment research. Also undertaken were studies leading to the identification and measurement of trace quantities of proprietary flotation agents used in base-metal milling, and of the contribution to water pollution by mine and mill wastes carried to the receiving waters in colloidal suspension.

Preliminary planning of a pilot-plant laboratory, to be constructed at the Canada Centre for Inland Waters at Burlington, was carried out; the proposed facilities are to be made available for applied research on water and wastewater treatment from bench-scale to pilot-scale in prototype equipment. The active participation of other government agencies, universities and industry is expected to make the facility a focus of inter-agency collaboration in this very important activity in water-pollution control.

Water Chemistry Subdivision

During the year, emphasis was placed on the strengthening of the analytical laboratory capability and on developing methodology to provide the necessary broad basis of support for the growing water-quality-data collection and water and wastewater-treatment research. Priority was given at the laboratories at Ottawa, Moncton, Calgary and Burlington to the acquisition and use of automated analytical equipment to increase the ability of the laboratories to conduct many of the analyses which are carried out routinely. Emphasis on the determination of water-quality parameters used to evaluate pollution from municipal, industrial and agricultural sources also continued to grow. Plans were made during the year for the enlargement in 1969 of the laboratory work areas at Ottawa, Moncton and Calgary, to accommodate not only the continually growing workload resulting from expanding field work but also the continually growing range of analyses which are now required in the evaluation of water pollution.

The Burlington unit, housed in temporary trailer laboratories, continued to staff shipboard and shore-based laboratories for the water-chemistry-monitoring cruises carried out by the Great Lakes Division, as well as to provide support for research being conducted on the Great Lakes by the Fisheries Research Board.

The Regional Laboratories at Moncton and Calgary continued to operate at capacity, carrying a major responsibility for the expansion of the water-quality networks in the eastern and western regions and providing direct support to government and private water-resource studies and special research projects.

The Division continued to assist the Department of National Defence and the Department of Public Works on boiler-water-treatment investigations pending the re-assignment of this function in 1969.

The development of essential analytical methodology for the measurement of water-quality and pollution parameters continued to be a major undertaking of the Water Chemistry Subdivision. The need to adopt methods to measure substances having very low concentrations in water is becoming more evident as the significance of even trace quantities of some pollution parameters becomes appreciated. The analyses of nitrogen and phosphorus are examples of these micro-methods. Equipment was acquired for the measurement of pesticides and petroleum-based hydrocarbons in water, both of major concern in water pollution.

The Division continued its participation in the activities of the American Society for Testing Materials, and maintained liaison with the U.S. Department of Health, Education and Welfare, Public Health Service, and the U.S. Water Pollution Control Administration to keep abreast of new analytical procedures and to participate in methods evaluation.

ENERGY DEVELOPMENT GROUP

The Energy Development Group pursues the broad mandate given the Department to examine energy in all its forms—coal, oil, gas, uranium, and conventional and nuclear generated electric power—to ensure that national development policies are related in the most effective and economic way to Canadian needs. The work of the Group is organized in terms of the principal energy sectors: electrical energy, oil and gas, coal, uranium and atomic energy.

As the size and complexity of Canada's energy industries have increased to meet the demands of a rapidly expanding economy, there has developed an urgent need for a body responsible for the coordination of energy policies in the total energy context. Not only must the expansion of one energy resource be carried out in full awareness of other energy alternatives, but the implications of such developments for other national and regional economic factors must be fully understood and reflected in government policy. This role of coordination of energy programs and policies rests with the Department of Energy, Mines and Resources, with the Assistant Deputy Minister (Energy Development) being the Department's principal adviser on energy matters.

There are many changes taking place in all areas of energy development. In the field of electrical power generation, for example, Canada is in a period of wide-ranging development. In British Columbia, Quebec, Manitoba and Newfoundland—areas rich in water resources—hydro-electric projects with an ultimate total potential of over 15 million kilowatts are now under construction. This potential alone is equivalent to all the electrical capacity that was installed in Canada up to the year 1956. Other provinces are building conventional coal or oil thermal electric plants, while Ontario will have over 5 million kilowatts of nuclear capacity under construction by 1970. Thus, the developments in electrical power generation have implications for all energy sectors. Against this background of change the Energy Development Group is cooperating in studies and joint programs from Newfoundland to the Yukon. A joint federal-provincial study of power-supply alternatives for the Island of Newfoundland was completed within the past year. The final report on the Bay of Fundy tidal-power studies was scheduled for the fall of 1969, and a joint study with the United States of possible markets for Yukon River power has been initiated.

Change and expansion are also very much in evidence in other sectors of the energy economy, and the Energy Group's activities are concerned with the related policy and development. New oil-supply patterns are in the offing, particularly as the result of a major oil discovery in Alaska and exploration in Canada's north and offshore areas, while North American markets are calling for more and more Canadian natural gas. Canada has entered a new period of major coal development based on the establishment of economic markets for coal from the western provinces. After several years of depressed activities, the uranium industry is moving into a period of exploration comparable to that of the mid-1950's. In keeping with changes in this sector, a new uranium policy has been developed.

The dynamic energy economy in Canada results from the growth within each sector and from inter-energy competition. Consequently, policy considerations in any sector must have regard to the total energy picture. The following individual projects and developments relative to each of the energy sources must be studied and assessed in terms of inter-relationships with other energy sources whenever policy recommendations are to be made. All studies and recommendations are directed towards the maximum development of Canada's energy resources to ensure adequate supplies of low-cost energy to the domestic consumer, to encourage exports of energy exceeding domestic requirements and, in total, to meet the rising energy demands of a modern industrial nation in a manner best suited to its political, social and economic objectives.

ELECTRICAL ENERGY

Atlantic Provinces Power Development Act

Responsibility for the Atlantic Provinces Power Development Act was transferred to the Minister of Forestry and Rural Development (subsequently the Minister of Regional Economic Expansion) in July 1968, but the Energy Group continued its advisory role in respect to the administration of this Act.

Capital assistance to date under this Act has helped to establish an interconnected power system in New Brunswick and Nova Scotia and an island-wide transmission system in Newfoundland.

During the year, the coal-subvention provisions of this Act were reviewed and recommendations prepared on the future use of this element of support. Study continues on the capital-loan provisions and the relationship of this type of assistance to the broader regional economic objectives of the new Department of Regional Economic Expansion.

Newfoundland Power Supply Study

A study of the generation-expansion alternatives for the Island of Newfoundland, sponsored by the Energy Group of the Department as a joint undertaking by the federal government and the Newfoundland and Labrador Power Commission, was completed. The conclusions of this study were reviewed in detail but are subject to further study when specific data concerning the future development of hydro-electric power on the Churchill River in Labrador, below Churchill Falls, become available.

Trans-Canada Grid Study

The report of the Federal-Provincial Working Committee was presented to the Federal-Provincial Ministerial Committee on Long-Distance Transmission and was tabled in the House of Commons on 11 December, 1968. The recommendations for reinforcement of regional interconnections are being followed as opportunity arises to encourage such strengthening of electrical ties. The Energy Group participated in discussions on two such interconnections during the year.

Yukon River Development

An exchange of notes took place between Canada and the United States on December 19, 1968, which provides a basis for discussion of the market potential for power from possible development of the Yukon River. This represents an initial step towards assessing the advantages to area development from hydro-electric power which could be generated by the diversion of part of the headwaters of the Yukon River to a generating station on tidewater in southeastern Alaska or northern British Columbia.

Initial discussions have taken place with representatives of the Alaska Power Administration and the United States Department of the Interior. While responsibility for the study rests with the Department of Energy, Mines and Resources, the Government of British Columbia, the B.C. Hydro and Power Authority and the Department of Indian Affairs and Northern Development are also participating. The market study is being coordinated with activity related to the transportation study of the region being carried out by the Department of Transport.

Quebec – New Brunswick Intertie

The Energy Group carried out a study of the technical feasibility of, and the possibility of federal government support for, a proposed high-capacity DC interconnection between the power systems of New Brunswick Electric Power Commission and Quebec Hydro; this included an assessment of the possible benefits of such an intertie to the Maritime Power Pool comprising New Brunswick, Nova Scotia and, in the future, Prince Edward Island.

Atlantic Tidal Power Study (Bay of Fundy)

The Energy Group continued to participate in the study of the Bay of Fundy tidal-power-development scheme, the transmission requirements to market this power, and the impact of such a development on the regional power system and on regional economic development. The technical elements of the tidal-power investigation were essentially completed during the year, and preparation of the final report commenced.

Nelson River Development

A review committee, required by the Federal-Provincial Nelson River Agreement, was established and held its first meeting. The Assistant Deputy Minister (Energy Development) is the chairman of this committee, which will review progress in implementing the agreement. This agreement provides for the construction by Canada of a transmission system, comprising a 560-mile transmission line and terminal facilities between the Kettle Rapids power development on the Nelson River and a terminus near Winnipeg; upon completion the facilities constructed by Canada will be leased to the province of Manitoba which will also operate and maintain the system.

Columbia River Development

The Assistant Deputy Minister (Energy Development) continued his duties as Canadian chairman of the International Columbia River Treaty Permanent Engineering Board which is charged with ensuring that the objectives of that Treaty are met.

The Permanent Engineering Board staff, located in Vancouver, conducted continuing studies relating to the operation of the Canadian Treaty projects, Duncan, Arrow and Mica, leading to the drawing up of the Operating Agreement provided for in the Columbia River Treaty.

The Assistant Deputy Minister also continued as federal chairman of the B.C.-Canada Columbia River Advisory Committee which assists a federal-provincial committee of ministers to facilitate implementation of the treaty by Canada. The federal chairman of the ministerial committee is the Minister of Energy, Mines and Resources.

Research

Consultation was provided to the Department of Industry, Trade and Commerce leading to approval of a development project by a Canadian electrical manufacturer in high-voltage direct-current-transmission equipment. Discussions are continuing in relation to establishing a possible test site for prototype evaluation in a later stage of the development.

The Energy Group assumed responsibility for a review of the national interest in the establishing in Canada of high-voltage and high-power electrical research facilities, and for a consequent study on the possibility of providing federal assistance for specialized research facilities of this nature.

OIL AND GAS

The oil-and-gas industry is one of the most dynamic sectors of the Canadian economy, and its growth in the past 20 years has had a major impact on regional and national development. The Energy Development Group continuously appraises trends in oil and gas exploration and production, transportation, processing, and marketing in Canada and on an international scale. The appraisal of industry developments forms the basis for studies and recommendation on policy. The Department coordinates these studies when several government departments are involved. The Department is concerned with supply and demand as they relate to short- and long-term planning.

During the period under review, important oil discoveries were made in northern Alaska, and many other events of a national and international nature had major implications for the oil-supply-and-demand pattern in North America. To assess the importance of these events to the Canadian economy, the federal government established a Task Force on Northern Oil Development. The Task Force, chaired by the Deputy Minister of the Department, is concerned with engineering and economic assessments of transportation methods, both pipeline and tanker, that might be used to transport and market oil from Arctic areas to continental and world markets. Particular interest centres on the results of the trial voyage of the tanker *Manhattan* through Arctic waters from the Atlantic Ocean to Alaska to determine the feasibility of establishing a year-round tanker route from the Prudhoe Bay oil area in northern Alaska to markets on the east coast of North America and in Europe.

The Energy Development Group advised other departments of the federal government on oil and gas policy related to the responsibilities of those departments and provided information to industry and the general public on oil and gas developments in Canada and abroad. Close liaison on oil and gas matters was maintained through field work, meetings and conferences. A member of the staff serves on the National Advisory Committee on Petroleum Statistics established by the Dominion Bureau of Statistics in 1968.

Participation in the Science Council of Canada study of the earth sciences involved an appraisal of the contributions of geology, geophysics and geochemistry to oil and related mineral development in Canada. The Science Council study was particularly concerned with the scope, direction, and effectiveness of scientific activities in the development of economic resources to meet the huge energy and mineral demands of the future.

COAL

The coal industry has been going through a period of major change in which the industry in Nova Scotia and New Brunswick has been re-adjusted to reduced markets and higher costs, while that of western Canada has been entering into major export contracts and proceeding with the development required to meet delivery schedules under these contracts. With the establishment of the Cape Breton Development Corporation, a Crown company, to administer the coal mines of Cape Breton at lower production levels and to encourage the development of a more diversified economy and the concurrent rationalization of the New Brunswick coal industry, the federal assistance formerly provided in the form of subventions has been replaced by more progressive developmental measures. In western Canada, where the coal industry is entering a new

economic phase, subventions will not be required and federal-government interest and support is being expressed in terms of coal research and the provision of suitable harbour facilities.

With the phasing out of subvention obligations, the government has proposed that the Dominion Coal Board be dissolved. The remaining responsibilities of the board would be carried out in the Department of Energy, Mines and Resources. In anticipation of this change, Departmental officials worked closely with the Board's staff to ensure a smooth transition and continuing attention to coal-industry matters. At the same time, the industry was encouraged to establish an industrial association to act on its behalf in maintaining effective liaison with the federal government.

During the past year arrangements were completed to phase out by 1971 all transportation subventions, as authorized in 1962, to Alberta and British Columbia producers shipping coal by rail to Vancouver for transshipment to foreign markets. For the industry in the Maritime Provinces, arrangements were completed with the New Brunswick government for a new form of financial assistance by the federal government which will provide for the gradual phasing out of operations at the Minto coal field and the development of alternative forms of industrial activity.

Although the large coal imports into central Canada from the United States continue, the growth in coal exports to Japan from Alberta and British Columbia gives promise of a trade balance in coal by the mid-1970's. To further encourage economic trends in the industry, coal policy has been undergoing a major change. Instead of subsidization, largely designed to retard the decline of non-productive mines until alternate sources of employment could be found, the government now emphasizes resource development and product research for new coal markets. This is in line with one of the fundamentals of Canadian energy policy—that of encouraging maximum development of economic sources of supply for domestic and export markets.

URANIUM AND ATOMIC ENERGY

With market prospects for Canadian uranium improving as planning and construction of nuclear power plants proceeds throughout the world, attention has been directed towards a review of Canadian uranium policy. The present policy was announced in 1965 and provided for exports under safeguards to ensure that Canadian uranium was to be used only for peaceful purposes, and it also provided for the stockpiling of uranium so that Canadian mines could continue operating while markets were being developed. One aspect of the review would be to ensure that the policy take full account of the Canadian public interest in the new circumstances of growing world requirements and, at the same time, act to curtail the spread of nuclear armaments.

Administration of the federal government's uranium policy will be designed to encourage the growth of the Canadian primary and secondary uranium industry through maximization of its opportunities in the world uranium market. To this end, the Energy Group continued its coordination for departments of the federal government concerned with uranium policy. Matters under study included stockpile programs, possibilities of the establishment of uranium-enrichment facilities in Canada, and export opportunities.

RESOURCE ADMINISTRATION DIVISION

The Resource Administration Division administers and manages the federal interests in mineral resources offshore from Canada's west and east seacoasts and in the Hudson Bay - Hudson Strait region, as well as those federally-owned mineral rights in the provinces that become available for disposition. During the year the Division was transferred to the Energy Development Group from the Mineral Development Group.

In addition to the foregoing the Division gives policy recommendations and advice in regard to the offshore resources, provides representation and expertise in dealing with interdepartmental, federal-provincial and international offshore matters, and provides for coordination between government and industries concerned with utilization of offshore areas.

Offshore Mineral Rights

There have been differences of opinion between the federal government and the governments of the coastal provinces concerning their respective rights to the mineral resources off the west and east coasts. As a step towards resolving these differences, the federal government, in April 1965, after considerable consultation with the provinces, referred the question of ownership and jurisdiction over the resources of the seabed and subsoil off the west coast to the Supreme Court of Canada for an advisory opinion. The reference was pleaded in March 1967. In November 1967, the court

handed down the opinion that ownership and jurisdiction over these resources lie with Canada and are, therefore, the responsibility of the federal government.

The Prime Minister made a comprehensive announcement of the offshore situation in the House of Commons in December 1968, and followed this up with a further announcement in March 1969. In brief, he announced the establishment of mineral-resource-administration lines to divide areas of federal and provincial administration. The areas landward of the lines were to be administered by the appropriate provincial government, which would receive all mineral resource revenues accruing therefrom, and the areas seaward of the lines were to be administered by the federal government. The Prime Minister further announced that the federal government is prepared to place half the revenues accruing from mineral exploitation within the federally-administered areas off the east and west coasts and in the Hudson Bay region in a single national pool to be distributed among the provinces on a basis acceptable to them.

Offshore Exploration

Expenditures in excess of $18 million were made by industry on Canada Oil and Gas Permits during 1968, about $5 million more than was spent the previous year. This brought the total expenditures by the various companies engaged in exploration in Canada's offshore areas to more than $60 million. In this connection, the Division authorized more than 30 separate offshore exploration programs and ensured that they were carried out in accordance with federal requirements.

Highlights of 1968 included: (1) the continuation of extensive drilling off the west coast, with nine exploratory wells completed and abandoned during the year (one of these, Shell Anglo Sockeye B-10, reached a depth of 15,656 feet and was the deepest well drilled in Canada during the year); (2) the marked increase in demand for Canada Oil and Gas Permits, with eight times as many issued as during the previous year; (3) the announcement that two $12-million semi-submersible drilling units would be constructed at Halifax for extensive drilling off the east coast, one program to begin in 1969 and the other in 1970; and (4) the announcement of the first drilling program for Hudson Bay, to be carried out in the summer of 1969.

Canada Oil and Gas Permits

A total of 2,393 Canada Oil and Gas Permits covering 161.5 million acres were issued in offshore areas during 1968 as follows:

East Coast	1,463 permits	103,932,678 acres
West Coast	23 permits	964,976 acres
Hudson Bay	907 permits	56,587,207 acres

This brought the number of offshore Canada Oil and Gas Permits (except on the Arctic coast) to 5,356, covering 382 million acres, as follows:

East Coast	3,367 permits	255,254,816 acres
West Coast	256 permits	15,772,623 acres
Hudson Bay	1,733 permits	110,609,115 acres

The total revenues received during the fiscal year 1968-69 on behalf of offshore permits, including permit fees, transfer fees, forfeitures, maps and exploratory licences, amounted to $641,564.95, most of which was derived from permit fees.

Mineral Claims

Offshore mineral claims are issued for mineral rights other than oil and gas rights under the Canada Mining Regulations. A mineral claim usually covers an area approximately 1,500 feet square (about 52 acres). Five offshore mineral claims were recorded during 1968 off the east coast. This brought the total number of mineral claims to 356, distributed as follows: east coast, 161; west coast, 108; Hudson Bay, 67. Revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1968-69 amounted to $1,296.

Federal Lands in the Provinces

During 1968, twenty-three oil and gas leases were issued, five in Alberta and eighteen in Saskatchewan. This brought the total number of federal oil and gas leases in the provinces to 271. The revenues received during the fiscal year 1968-69 on behalf of oil and gas leases, including royalties, lease sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $310,785.92, most of which was derived from royalties.

DEPARTMENT OF

ENERGY, MINES AND RESOURCES

OTTAWA, CANADA

annual report 1969-70

Hon. J. J. Greene, Minister

CANADA

Department of
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Deep-sea offshore drilling rig.

New Directions

The objective of the Department of Energy, Mines and Resources (EMR) is to enhance the discovery, development and use of the country's mineral and energy resources and broaden our knowledge of Canada's landmass for the benefit of all Canadians. To attain this objective the department devises and fosters national policies based on research and data collection in the earth, mineral and metal sciences, and on social and economic analyses. This mandate specifies the need for capability in all phases of non-renewable resources management.

The challenge posed by such a mission in a country like Canada, which is so dependent for its present state of social and economic well-being on its mineral and energy resource industries, is central to national purposes, basic to federal-provincial relations and essential to our role in the international community.

As Canada entered into the new decade, the mineral industry was setting production records and providing more and more new wealth for Canada. But the nation was also confronted with a number of complex, if not

critical, issues in the mineral and energy economy, as for example: the orderly development of the resource base and the expansion of domestic and foreign markets; capital availability and issues relating to ownership and control; new tax policies; major programs requiring new policies in the Arctic frontier and offshore in the ocean frontiers; economic growth and the establishment of environmental quality standards; the need to integrate energy supply and demand patterns and to achieve reasonable energy costs, and the fostering of viable coal and uranium industries; the development of transportation arteries at realistic costs, and the stability of communities dependent on the resource industries for the well-being of their people and the future of their children.

These and other problems have brought into sharp focus the need to develop and implement coherent and effective mineral and energy policies and to improve Canada's technological and managerial competence in these fields.

The scientific and technical organization which EMR has built up over the years provides the capability to assess energy and mineral resource potential and improve the means to discover, develop and use it.

Already the nation's leader in earth sciences, the Department provides basic physical information about the earth, which contributes to man's understanding of his planet and includes integral environmental projects and studies. The scientific knowledge gained during the implementation of these programs is important to the work and planning of many federal departments and agencies, at all levels of government in Canada, as well as to a host of commercial and industrial organizations.

The Department's responsibilities have been sharpened by the transfer of some of its activities (notably astronomical and astrophysical research, and water resource programs) to other agencies — a restructuring that has given a new thrust to mineral, energy, earth and related socio-economic sciences.

ENERGY RESOURCES

Nowhere are the complexities of resource development better illustrated than in the field of energy.

It is clear that meaningful policies can no longer be developed for a single energy commodity, such as coal, gas, or electric power, without careful consideration, from the viewpoint of the whole national economy, of the impact of one energy source on another. Alternatives posed by present and projected technological advances require careful study, for their selection imposes subtle and wide-ranging effects. What are our existing and projected sources of energy? What proportion of these sources is economically recoverable with today's technology? With tomorrow's? To what extent does Canada have energy to spare for export? What systems should best be developed to transport it? What are the ecological implications? What policies should be developed to control foreign ownership of energy resources? Should the government itself be more active in resource development?

Part of the urgency of coming to grips with these problems stems from the phenomenal demand for Canadian energy. Domestic requirements are growing at an average annual rate in excess of four per cent and thus Canada's energy requirements will likely double over the period of the next 17 years. In addition to ensuring adequate energy supplies for the domestic market, there is considerable inducement to export energy because of favourable balance of payments effects, the incentive the larger market gives to earlier and rapid development of Canadian reserves and the stimulus to the development of the basic infrastructure of a regional economy.

One of EMR's most fundamental and pressing projects, therefore, is to complete an inventory of Canada's energy sources and a forecast of domestic needs. This will take into account 1) the supply, based on earth science data, and 2) the potential demand, based on the best forecasting technology and consumer market research.

At the same time EMR's energy specialists continue to monitor and assess current trends — regional, national and international — affecting any and every facet of the energy industries. This research emerges in the form of advice and policy recommendations leading to a fully coordinated approach to energy problems.

The task is not an easy one, for each sector of the energy economy has complex problems of its own. For instance, EMR specialists in electrical energy are concerned with various forms of power-system planning and the siting of generating and transmission facilities. A wide range of regional studies is undertaken in con-

junction with provinces, e.g., the feasibility study on the tides of the Bay of Fundy, the Power Market Study of the Upper Yukon River, and the Nelson River Power Development.

In the domain of oil and gas, Canada-U.S. relations are of prime importance. EMR's oil experts are assessing such matters as the U.S. quota system against Canadian oil exports, the ramifications of the Prudhoe Bay discovery, the problems of northern pipelines and marine transportation of oil and gas, and the ecological and pollution control problems associated with oil and gas development.

The economic implications and impact of oil and gas discoveries off the Atlantic Coast are high on the Department's priority list from a policy and administrative point of view. EMR is, in fact, both trustee and manager of the mineral resources off Canada's east and west coasts and in Hudson Bay and Strait. For more than a decade the Department has, through its resource management policies and its own work in submarine geology, played a key role in encouraging industry to explore for resources in the offshore. With over 600,000 square miles now under exploratory permit to a large number of oil companies and with the exploration activity rapidly increasing, a large responsibility is placed on the Department to set standards and enforce regulations which will ensure safe and pollution-free operations. In response to this increasing responsibility, EMR has established the Atlantic Geosciences Centre at Dartmouth, N.S., for the study of marine geology and geophysics on the continental shelves and in the deep ocean, and is providing office and laboratory facilities where cores and cuttings from offshore wells can be studied and stored. The facilities will serve as a base from which to evaluate and regulate activities concerning the exploitation of Canada's offshore mineral resources.

In the west, EMR has stayed with the coal industry through hard times and, in several ways, has contributed to the resurgence of the western coal industry. The Department is also studying the supply-demand picture affecting Ontario coal consumers and their dependency on imported coal and assessing technological improvements in coal mining, processing and transportation.

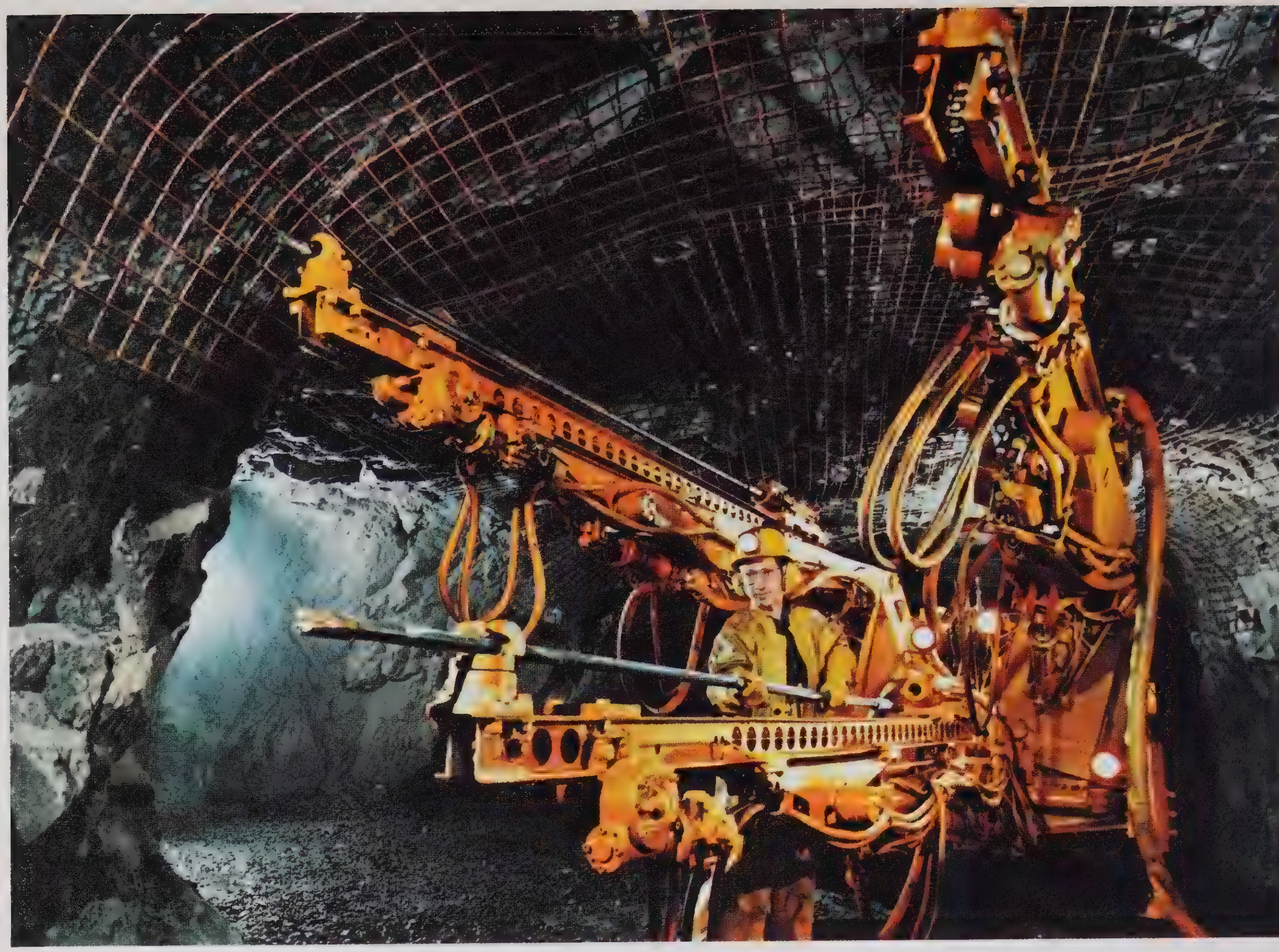
In the area of uranium and nuclear energy, there are many activities requiring immediate and in-depth attention. Indeed the strategic importance of uranium, the fact that Canada has large uranium reserves and a substantial government uranium stockpile, and the economic value of uranium both for export and domestic use are factors demanding the development of sound and flexible national policies and guidelines.

Canada's energy position is also being strengthened through geological investigations and fuels research.

Of some 500 continuing projects under way at the Geological Survey of Canada, a branch of the Department, a large number are directly, or indirectly, concerned with energy development. Many are conducted by the Institute of Sedimentary and Petroleum Geology in Calgary. The range of projects extends from field work in sedimentary basins of the Arctic to the development of new methods for petroleum prospecting, and includes many other field and laboratory investigations. In 1970 the Survey completed a study of the Mackenzie Delta and valley to provide geological information of importance to possible pipeline construction.

Meanwhile, advances in energy technology are being made at EMR's Fuels Research and Metals Reduction and Energy Centres which, in essence, are researching better ways of using and conserving Canada's reserves of coal, petroleum and natural gas. The Centres are currently giving special attention to combustion research with a view to the reduction of air pollution, the refining of low-grade oils, and the development of metallurgical coke from Canadian coal. Their work so far has done much to open up new markets for Western coal in Japan. They are currently studying the possibilities of using a water-slurry pipeline as a more economical way to move coal from strip mines in the Rockies to tidewater ports.

In the field of refining, fuels scientists are developing methods of converting the bitumen of the Athabasca tar sands to synthetic crude oil. These Canadian deposits contain some 600 billion barrels, one of the greatest sources of oil in the world. The challenge is to find processes that will permit the economic extraction and use of this tremendous potential and also that of other heavy oil deposits in Western Canada.



Drill jumbo in use, Sudbury nickel mine.

MINERAL RESOURCES

Departmental programs in reserves determination, mining, metallurgy and the processing of industrial minerals involve both policy formulation and scientific research in laboratory and field. In addition, factors, such as the strategies of foreign countries and multinational firms to obtain the maximum benefit from Canada's mineral base are proving a challenge of increasing importance. Thus the Department is focussing greater effort on policy formulation and programs to increase returns from exports and to improve the social-economic effects from mineral industry development throughout the nation.

EMR must ensure that the country's needs for mined products are met and it therefore monitors the performance of the industry with a weather eye on its economic health and the factors that affect it.

To identify and evaluate trends affecting the industry, EMR's resource economists study the entire spectrum of mineral industry activities from geologist to user: exploration and development, processing, transportation, marketing and consumption. The information provides a basis for decisions to be taken within the Department and contributes to the development of resource policies. Typical recent projects have involved such diverse matters as a cooperative study of minerals management undertaken with the Province of British Columbia: research leading towards a federal-provincial program for mineral development in Manitoba; special studies of concern to Newfoundland, New Brunswick, and Quebec in collaboration with the federal Department of Regional Economic Expansion, and cooperative planning for resource development in the north with the Department of Indian Affairs and Northern Development.

Other projects concerned the White Paper on Tax Reform and its impact on the industry, the potential benefits that might be derived from future mineral development in northwestern Canada if a new railway network were developed and other programs touching on some 60 mineral commodities.

EMR economists sit on numerous intergovernmental and international bodies concerned with mineral matters.

Highlighting developments in the industry in 1970 was

the changing pattern of trade in mineral products, with Japan emerging as a leading customer, especially of products from the West. Of all minerals imported by that country in 1969, one third of the potash, 50 per cent of the asbestos, 36 per cent of the molybdenum, one third of the lead and zinc concentrates, and 50 per cent of the nickel came from Canada. In addition, Japanese capital is participating in no less than 15 different copper development projects in the Canadian west. And the growing Japanese steel industry has been using Canadian iron ore for some years. Now strip mining of coking coal for these mills is becoming an important industry in Alberta and British Columbia. Shipments from the Pacific Coast could well be in the 30 million-ton-per-year range by 1975.

The federal government has recognized the importance of this new relationship. In December 1970, the Honourable J. J. Greene led a mission of government officials and mining industry representatives to Japan for talks at the level of the Japanese government and at senior business levels in Japan regarding the general trading and investment posture of Japan in the Canadian mineral industry and regarding a whole host of issues concerning the market performance of mineral commodities, Japanese demand and supply, further processing, Japanese investment in Canada and Canadian investment in the mineral processing industries in Japan, and other topics.

EMR's responsibilities in mineral development also extend into the laboratory and the field.

EMR's work in geology and geophysics provides a foundation for discovery and evaluation of Canada's mineral resource potential. Summer field parties were located in almost every province and every physiographic region of the country and in many locations of economic interest to the mining industry.

Other EMR geological programs deal with economic geology of mineral occurrences and some seek to improve the technology of prospecting and exploration. More of these programs are described in the body of this report.

Meanwhile, EMR scientists are working to improve the technology of mining, the processing of ores and minerals, and, through research in physical metallurgy, the development of new alloys and metal fabricating methods, ultimately broadening the market for Canadian metals.

Projects in mining technology, for instance, are producing answers to practical problems. For example: How can current methods of drilling, blasting, crushing and grinding be improved and made safer and less costly? How can the stability of a mine excavation or the sides of a quarry be determined? How can systems engineering be best applied to mining operations?

In answer to a need for greater government-industry cooperation, EMR set up a National Advisory Committee on the Mineral Industry to advise the government on a wide variety of issues affecting the industry. One of these is the maintenance of realistic environmental standards in the national interest.

Canada's mines and smelters use over a billion gallons of water a day, and produce 300 million tons of waste tailings a year. Much of this material is returned underground as fill. To date, a total of 130,000 acres of land have been used on which to store the remainder. Between now and 1975, a departmental survey shows that the mining and primary metallurgical industries plan to spend an estimated $500 million on environmental control.

In one environmental project, EMR researchers used a probe mounted on a helicopter to measure gas flows from the tall stacks now used to disperse sulphur dioxide. They hope, by studying the mechanism of sulphur dioxide dispersal, to establish optimum heights for such stacks. Other projects are aimed at the development of processes that avoid or prevent the production of sulphur dioxide. The extraction and processing aspects of mining pose many scientific and technological questions which EMR scientists are attempting to answer.

A good example of a successful commercial development resulting from recent departmental research is the Leigh oxygen probe. This instrument, developed by EMR's physical metallurgists, helps steel makers detect and measure unwanted oxygen in the molten metal. The project was carried on cooperatively by EMR, the Canadian steel-making industry, and Leigh Instruments Limited. The probe is now being marketed by the Canadian company to steel mills around the world.

WATER RESOURCES

Highlights of the Department's research and policy-making activities in water resources were the passing of the Canada Water Act to control water pollution and the successful completion of Hudson 70. The latter, the epic voyage of EMR's oceanographic ship around both North and South American continents, was a major navigational 'first'. Even more significant in the long term were the scientific results.

The 11-month, 41,000-nautical-mile expedition, resulted in the collection of a great mass of data on the Atlantic, Antarctic, Pacific and Arctic Oceans, contributing greatly to world oceanography and to the development of Canada's undersea resources.

Apparatus for thermal destruction of DDT, Fuels Research Centre, Mines Branch.

EARTH SCIENCES AND LAND-MASS MANAGEMENT

The Department continues to be responsible for carrying out the basic research programs and the technical surveys necessary for engineering and resource development purposes.

These include field and air surveys, topographic and other forms of mapping and geological and geophysical research. The programs are designed to further man's knowledge of the solid earth and thereby assist the nation in meeting its economic, social and other needs.

As the government agency for the preparation and production of maps (topographic, legal, electoral and other), EMR is providing data that is fundamental to national development and resource management. Maps at four miles to the inch now cover the entire country and those at one mile to the inch cover about 35 per cent. Annual sales of maps are nearing an all-time high of three million. Soon to be completed is the fourth edition of the *National Atlas of Canada.*

In earth physics, the Department undertakes research and field work in geomagnetism, seismology and gravity. Apart from their value to world science, these programs

are of considerable practical importance — for instance, to navigation by air and sea, to mineral exploration and even to the detection of nuclear explosions.

Geological surveys and research contribute to the land-mass management program mainly through the gathering of data on unconsolidated earth materials, land forms, rock structures and, in general, on the physical geography of Canada — information that is vital to a host of matters (e. g. rural and urban planning, efficient land use, structural engineering, environmental control and advice on both the use and misuse of terrain). Particularly significant is its value to northern development and the solution of terrain problems associated with it. One current area of activity relates to the terrain problems which might be encountered by pipelines along the Mackenzie Corridor.

Over the years EMR activities and facilities on Canada's polar continental shelf have paved the way for numerous developments in the Arctic and contributed to Canada's Arctic achievements. It goes without saying that adequate information about the Arctic and its environment is basic to the development of national and regional policies affecting it.

EMR carries out a multi-disciplined research effort covering the undersea continental shelf fringing the Arctic coast of Canada together with adjacent parts of the Arctic Ocean basin and the islands of the Canadian Archipelago. Scientists from other agencies also use EMR facilities for work in their own disciplines.

Looking to the future, EMR is moving rapidly into the field of space technology. The Department will soon have the means to obtain basic physical information about the country from instruments aboard orbiting satellites in NASA's Earth Resources Technology Satellite (ERTS) program.

A four-year agreement has been signed with NASA which will provide Canada with satellite photos and other data free of charge. At the same time Canada, under the leadership of EMR, is organizing a program of remote sensing by high altitude aircraft to supplement the satellite data with required detail.

Over 200 scientists from across the country have been involved in working groups for the past year studying how Canada can best develop a remote-sensing technology embracing both airborne and orbital sensing. Contracts for $200,000 worth of specialized sensors for the program have already been awarded to various Canadian organizations.

Measuring gravity at Arctic Ocean camp on polar ice.

The existing receiving station at Prince Albert in Saskatchewan will be used for reading out satellite data for all Canada with the exception of the Atlantic Seaboard. Data from the Atlantic Provinces will be received by a nearby U.S. station and the tapings sent to Canada for processing. All data collected will be sent to a Ground Data Handling Centre in Ottawa, where it will be corrected, reproduced and distributed to government agencies, universities and other organizations — an estimated 900 users in all. Capital cost for the station and data centre will be about $4.6 million.

The ERTS satellites can provide complete coverage of the world in 17 days. Photos show such variations as changes in snow and ice cover, changes in leaf cover in the forests, changes in water levels in lakes and rivers and even changes in surface temperature.

Canada is particularly anxious to obtain satellite photos in areas of critical interest such as the Beaufort Sea (ice cover), the Mackenzie River Delta (permafrost, possible damage to the environment from mineral exploration), the Mackenzie River valley (in anticipation of the proposed pipeline), the Prairies (crops), the Great Lakes (pollution), Hudson Bay (ice), the Gulf of St. Lawrence (oceanography) and the continental shelf on the Atlantic coast (ocean pollution).

ADMINISTRATION PROGRAMS

In the immediate future, the Department's success in carrying out its mandate may very well be determined by its success in coordinating and giving thrust to a number of diverse scientific and socio - economic programs. A prime concern, therefore, is to develop management structures necessary to make such an organization work effectively, with the agility to respond immediately to changing situations. Equally important is the need to provide the various departmental sectors with efficient support services (i.e. in planning, personnel, finance and administration, computer sciences and public relations and information). It should be added, however, that the Computer Sciences Centre is serving not only the needs of EMR but those of the Water Resources Branches of the Department of the Environment. The Department recently has signed a contract for rental of a large-scale CDC 6400 computer system with seven terminals located in various EMR buildings in Ottawa.

It is expected that EMR's central services and a number of other units of the Department will by 1973 be housed in a new high-rise building to be erected on the Booth Street site.

CONCLUSION

An essential activity of the Department of Energy, Mines and Resources is to build a foundation of knowledge and expertise for the development of sound policy recommendations. This is vital to the effective management of Canada's mineral and energy resources and to the solution of many complex and interrelated problems in this field.

How these resources are developed and used will have a profound impact on the national economy and the lives of Canadians.

Mines and Geosciences Sector

SURVEYS AND MAPPING BRANCH

The Surveys and Mapping Branch is responsible for providing the survey data, maps and aeronautical charts required by Canada for security, administrative purposes and the management of national resources.

Survey activities during the year included the operation of some 60 field parties that conducted surveys for geodetic and mapping control, for cadastral and boundary work and for field checks of mapping.

The Topographical Survey Directorate achieved a new record of output in producing 704 maps, comprising new and revised mapping. The status for mapping now available in Canada is: Maps at 1:25,000 (or 2½ inches to one mile) number 645 and cover urban and industrial areas; maps at 1:50,000 (or 1¼ inches to one mile) number 4,650 and cover 35 per cent of Canada's territory; and maps at 1:250,000 (or four miles to one inch) number 920 and cover all of Canada's territory. There are also maps at smaller scales covering all of Canada. All of these maps are being revised from time to time.

Map reproduction during the year included 2,118 different maps and charts, and involved a total of 38.5 million printing impressions.

The development of an Automated Cartography system in the Branch made encouraging progress. Hardware and software requirements are being resolved and considerable practical experience is being gained in the cartographic needs of the mapping program and the ways in which automated techniques can establish accuracy and quality in the maps to be produced.

The fourth edition of the *National Atlas of Canada* is being produced at a rate of approximately four sheets per month. At the end of the fiscal year 65 of the 128 sheets of maps, indexes or texts etc. were in various phases of production beyond the research stage.

In order to promote and sell maps the Branch was represented at nine major shows, and 1,523 people were conducted on tours of the Branch divisions. During 1969-70, map sales reached an all-time high of 2.7 million.

External assistance by the Branch in support of the Canadian International Development Agency continued in the form of consultant services for surveying projects in the West Indies and Africa, and also summer training courses for overseas students. On the broader international scene Branch personnel attended many international congresses, thus indicating Canada's interest and competence in the field of surveying and mapping.

The Mapping and Charting Establishment of National Defence made a modest but worthwhile contribution to various field surveys, map compilation and printing

when its resources permitted. The co-operation of all the provinces and the U.S. Geological Survey in many aspects of the Branch's work contributed to a progressive year.

The text of this report indicates the variety and scope of the Branch tasks necessary to fulfill the duties as the federal agency responsible for national control surveys and mapping, which in 1969-70 produced a record of expansion and accomplishment.

FIELD SURVEYS DIRECTORATE

Geodetic Survey

Thirty-two field parties established horizontal and vertical control to extend and densify the existing national control-survey framework and to provide control for the national mapping program. A number of special projects were also carried out, and the survey continued its investigational projects.

The extension and densification of the first-order horizontal control framework was carried out in the Yukon and Northwest Territories and in five provinces. In the Territories the aerodist program was continued, and the network extended north from Wrigley down the Mackenzie River to the Arctic coast north of Inuvik. This project covered an area of 98,800 square miles, established 42 new ground stations and provided mapping control for 377 map sheets (1:50,000) in this area of very high interest to the petroleum industry. In British Columbia and Alberta the spur network, which had been completed from Golden to Mica Dam in 1968, was extended north to connect with existing surveys west of Jasper, and the main east-west network was extended east from Golden to connect with existing surveys near Calgary. In southern Ontario the network, which had been completed from Chatham to Sarnia in 1968, was extended northeast to connect with existing surveys near Strathroy; a new network to cover the gap in control along the north shore of Lake Erie was completed from St. Thomas to Tillsonburg. In Quebec the co-operative densification program was continued and the network extended westward as far as Quebec City. In Nova Scotia a new network was established from Halifax north to Minas Basin, west to Annapolis Royal and thence southeast to connect with existing surveys near Liverpool. A scale-control party measured existing lines in Nova Scotia and New Brunswick to improve the scale of the existing networks.

First-order levelling was done in seven provinces. Re-levelling was carried out in the vicinity of the Bennett Dam in northern British Columbia in a continuation of the study of crustal movements in the area. In Saskatchewan a grid of level lines was established in the Watrous-Saskatoon area. The Trans-Canada level line was extended eastward from the Saskatchewan-Manitoba border and was completed to Sault Ste. Marie, Ontario, a distance of 1,260 miles. A Geodetic Survey — Manitoba Hydro project was carried out in the vicinity of Thompson, Manitoba, to provide vertical control information for studies related to the development of hydro-electric power. A winter party continued this work in February-March 1970. Levelling of high precision, using the metric system, was continued in the International Great Lakes Datum re-evaluation program. The line was extended eastward from Beauharnois to Levis, Quebec; this line also serves as part of the Trans-Canada level line. In the Churchill Falls area of Labrador a new line was run from Esker to Sail Lake. In Nova Scotia new lines were run along the Bay of Fundy coast, and a number of river gauges and Bay of Fundy tidal gauges were connected in the course of the work. A small party re-levelled ties to 18 water-gauge sites along the St. Lawrence Seaway between Cobourg, Ontario, and Quebec City, and checked the stability of 12 deep bench marks in the area between Pickering and Trenton, Ontario.

Five astronomic parties worked in the Northwest Territories and in the provinces of British Columbia, Saskatchewan, Ontario, Nova Scotia, and Newfoundland. Thirteen Laplace azimuth stations were established, two old Laplace stations were re-observed, ten plumb-line deflections determined and an orientation azimuth determined for the Magnetic Observatory at St. John's, Newfoundland.

The project which provides vertical control for the Western Cordillera gravity program of the Observatories Branch, and also provides control for 1:50,000 mapping, was continued. A Geodetic Survey party extended control through an area of 3,000 square miles in the Quesnel Lake area of British Columbia, and through an area of 8,000 square miles which lies east of the British Columbia - Alberta boundary between Lake Louise and Jasper. A party from the Mapping and Charting Establishment, Department of National Defence, established a small amount of ground control, verified and identified additional existing control in an area of approximately 14,000 square

miles in the vicinity of Bella Coola, on the British Columbia coast. This control is being used in conjunction with super-wide-angle photography which was flown simultaneously with Airborne Profile Recorder measurements to produce the vertical control and mapping control by photogrammetric methods.

Assistance to provincial and municipal authorities in establishing co-ordinate systems of control surveys was continued at a reduced level. In Ontario the co-operative Ontario Department of Highways — Geodetic Survey horizontal-control program was continued in the western part of the Niagara Peninsula and in the Windsor-Merlin area. Horizontal control networks were also established in Sarnia, Sarnia Township, Dover Township and in the northern part of Burlington. Vertical control grids were established in Sarnia, Chatham and Burlington, and in the eastern section of Montreal, Quebec.

Three parties were engaged in establishing control for 1:25,000 mapping at Three Rivers, St. Hilaire, St. Jerome and Valleyfield in Quebec, and at Cornwall, Pembroke, Blenheim and Georgetown in Ontario. During the late fall and early winter two parties started on a project to provide control for 1:25,000 mapping in the Ste. Scholastique, Quebec, area where the new international airport will be constructed. A helicopter-supported party established horizontal control for 1:50,000 mapping near Berens River, Manitoba; Mistassini Lake-Chibougamau, Quebec; and Goose Bay, Labrador. Control for 1:50,000 mapping was also established in the vicinity if Ivujivik, Quebec, at the western end of Hudson Strait.

A number of special operations included the positioning of a number of air-navigational aids for the Department of Transport, and the establishment of horizontal and vertical control for large-scale plans of several Indian reservations and for the new National Park at Long Beach, Vancouver Island; this latter work was requested by the Department of Indian Affairs and Northern Development. At the request of the Observatories Branch a second-order traverse from Yellowknife to Rae, N.W.T., established positions of a series of points approximately two kilometres apart along the Yellowknife-Rae highway. While this work was primarily to provide control for a seismological project of the Observatories Branch, it will also provide horizontal and vertical control for legal surveys and 1:50,000 mapping in the area. In Nova Scotia a survey team from the Royal Engineers of the British Army carried out two projects under the general direction of Surveys and Mapping Branch. The first project was to establish vertical and horizontal control for a photomapping test project in the Cornwallis area. The second project involved the establishment of a horizontal-control densification survey by trilateration, the measurement of distances only, in accordance with specifications of the Geodetic Survey. The first project was completed, but the trilateration survey was only about 80 per cent complete when the team returned to England.

Several advanced experimental and theoretical projects were carried out to keep the Surveys and Mapping Branch in the forefront on new techniques and instrumentation.

Legal Surveys

The Legal Surveys Division continued its statutory general management and technical control of all legal surveys in Indian Reserves, National Parks and the Territories. During the year, the City of Whitehorse and the immediate surrounding area was officially established as a Co-ordinated Survey Area. Hence the placement of all new official survey monuments shall involve surveyed connection to reference points prescribed for the purpose and description in terms of the system of co-ordinates prescribed for the Area.

Work on two major survey projects, the subdivisions of the Six Nations Indian Reserve in Ontario and the Caughnawaga Indian Reserve near Montreal, continued. Although the field work has been completed on the former, some 20 official plans still remain to be compiled. In addition to the 15 field staff parties that were engaged on legal surveys, 29 surveyors in private practice were engaged to undertake a number of projects required by federal government organizations administering the lands involved. One hundred surveys were made in Indian Reserves in all the provinces except New Brunswick and Newfoundland, 21 in National and Historic Parks, and 30 in the Territories.

Survey plans examined numbered 398, of which 152 were surveys required by administering organizations and 246 were surveys required by outside organizations or individuals. The Division issued 278 sets of technical instructions, and 372 airline distances were computed and supplied for official purposes. Documents recorded in the Canada Lands Surveys Record numbered 581,

and some 75,000 document copies and extracts, and astronomical field tables, were dispatched. It was decided to microfilm all the Canada Lands Surveys Records. About ten per cent of this task was completed.

The Board of Examiners for Dominion Land Surveyors met five times. A new edition, the eighteenth, of the *Regulations, Rules and Instructions* was published. Of the 32 candidates who sat at the 1970 annual examination at centres in Ottawa, Edmonton and Calgary, four passed the preliminaries, one the intermediate, and five the finals, the latter qualifying for the Dominion Land Surveyor commission.

Two federally appointed commissions, chaired by the Surveyor General of Canada Lands, were active this year with respect to the survey and maintenance of provincial boundaries.

The Manitoba-Saskatchewan Boundary Commission continued the resurvey of the southerly 240 miles of this boundary. This year's program included the monumentation of 167 miles of boundary surveyed in 1967 and 1968, with 139 concrete monuments. The survey and clearing of 26 miles was completed through the rough terrain and dense growth of the Duck Mountains. This latter section involved placement of 20 concrete monuments. In all, 193 miles of boundary were completed and the Commissioner personally inspected various parts of the work.

The British Columbia-Yukon and Northwest Territories Boundary Commission began a program of maintenance of this boundary. This included resurvey and recutting of 5½ miles at the Liard River and resurvey of 12 miles in the mountain region east of the Haines Road. This latter work was extremely difficult because of snow conditions at the higher altitudes. In addition, 41 miles of boundary vista were recut and 60 monuments inspected at road crossings along the boundary and 160 miles of vista were sprayed with herbicides from helicopters. A total of 220 miles of boundary were inspected and maintained.

International Boundary Commission

The International Boundary Commission under the authority of the Treaty of 1925, and the International Boundary Commission Act (Eliz. II, Ch. 31, 1960) is responsible for the effective definition and marking of the boundary between Canada and the United States. In discharging these responsibilities inspection and maintenance operations are carried out annually, and all works within 20 feet of Canada's international boundary are effectively regulated.

The Commissioner for Canada and the Commissioner for the United States make joint inspections of the conditions along the boundary, and of the work of the various field parties engaged on sections of the Quebec, Ontario and Manitoba international boundaries.

Three Canadian field parties completed maintenance operations on the Quebec-Maine, Ontario-Minnesota and British Columbia-Washington boundaries. Operations on the Quebec-Maine Highland boundary consisted of the treatment of 54 miles of 20-foot boundary vista to control growth, and the inspection of 1,319 boundary monuments of which 30 required surveys for accurate relocation. A second Canadian party continued resurvey operations on the Rainy River, Ontario-Minnesota boundary to re-establish reference monuments which became lost or disturbed by erosion and construction operations, and to improve the overall accuracy of the original boundary survey in that area. Twenty-seven reference monuments were re-established and accurately tied to primary geodetic control. The program of controlling growth along the 20-foot vista through British Columbia was continued during the field season. Herbicides were applied by helicopter to 51 miles of boundary vista in selected areas eastward from the Okanagan Valley.

The new and improved methods of maintaining right-of-way vistas, over the past decade, have vastly improved the effective definition and marking of Canada's international boundary.

TOPOGRAPHICAL SURVEY DIRECTORATE

Photogrammetry Division

This report covers the first full year of operation since the division underwent an internal reorganization in late 1968. The reorganization grouped the personnel into seven mapping teams and was primarily designed to increase productivity by delegating authority and upgrading the knowledge and skill of the staff. These objectives have been achieved, resulting in a substantial increase in production. The details of the year's production are as follows:

Production of Mapping 1969-70

Scale	*New Mapping*	*Revised Mapping*	*Total*
1:25,000	22	55	77
1:50,000	456	154	610
1:250,000	3	14	17
Total	481	223	704

During the last two years, the Division has succeeded in clearing a backlog of approximately 250 1:50,000 maps that had been compiled but lacked cadastral information and final inspection. The Division has now reached a production schedule of 15 months embracing the complete mapping cycle from project initiation to clearance to the Map Production Directorate.

Many of the existing older maps in the settled areas of the country are out of date and are of questionable use to the public. Increased emphasis has been placed on the revision of existing maps over the past three years. It is estimated that in the year 1970-71, revision will account for 50 per cent of the maps produced by the Division.

The Division's role as a consultant to other federal agencies in the field of photogrammetric mapping continued to increase.

The Division reviewed 1:50,000 compilations by the British Columbia Department of Lands, Forests and Water Resources prior to reproduction by the Map Production Directorate. Thirty of these maps were examined in the past year.

The Research and Engineering section has continued its development of new and improved mapping methods and adjustment procedures. Areas of particular emphasis include photomapping, a program to improve the method of obtaining ground elevations by radar altimetry, computer programming for the adjustment of large blocks of mapping, use of color photography in mapping, investigation of new photogrammetric instrumentation, aerodist photography and methods for improving the identification of field control.

Aerial Photography Division

The Branch reorganization in 1968 united the National Air Photo Library and the Air Photo Production Unit to form the Aerial Photography Division as part of the Topographical Survey Directorate. This change was made to co-ordinate the operations of the two units involved in the dissemination and reproduction of aerial photo products to government, industry and the public.

The National Air Photo Library continued to receive more queries on the availability of photography for specialized uses and an increased volume of orders for aerial photographs. Both operations showed an increase of 6 per cent over 1968-69, a figure which has been maintained for the past 12 years. The Branch Photo Library in Calgary has now been in operation for a year and is gradually building up a clientele who find the service very helpful. Orders from this office are expected to increase greatly in the next year.

A new system was installed in the Library which enables the staff to produce copies of the photo-coverage index maps within minutes. This improvement has expedited the provision of this item to customers; it also results in reducing the administrative load on the unit.

Under agreements, the Division stores the negatives of provincial photography for Newfoundland, Nova Scotia, Prince Edward Island, Manitoba and Saskatchewan. This photography is as readily available to the public as federally acquired photography, for the Library holds reference prints and maintains indexes.

The Air Photo Production Unit suffered from the loss of a number of key personnel due to resignations, resulting in a decline in production. A determined effort by the staff of this unit to meet the demand for aerial photographs kept the effect of this production loss to a minimum.

The Hostert color-film processor was acquired and put into operation, providing a continuous processor for aerial color film for the first time in Canada. This equipment accounted for a marked improvement in the quality of color aerial photography.

The Division continued to provide training for technicians from developing countries under the external aid program, with one trainee from Kenya and another from Guyana.

This year saw increased demand for aerial photographic services. All indications point to an annual increase in demand of approximately 10 per cent for the next five

years. Of interest is the marked increase in requests for aerial photographs from educational institutions and the increase in orders originating from the U.S.A. There have also been many new applications of aerial photography during the year, one of which has resulted in large orders for photographs from statisticians for use in the 1971 census of Canada.

MAP PRODUCTION DIRECTORATE

Cartography Division

The Division is responsible for the compilation of general maps, aeronautical chart bases, electoral maps, bilingual-district maps and the 1:125,000 series. It provides cartographic support in the reproduction of N.T.S. maps compiled by the Topographical Survey by scribing, type selection, type affixment and hill shading. Maps received from the Topographical Survey for reproduction numbered 704. These included 77 at the scale of 1:25,000, 610 at 1:50,000 and 17 at 1:250,000. Derived map compilations produced by the Division totalled 176; these included six general and special maps, 25 1:125,000-series maps, 26 aeronautical chart bases, nine IMW maps, 71 electoral, bilingual, departmental miscellaneous and 39 for other departments of government. Drafting production for the year totalled 786 completed jobs. These included 88 at 1:25,000, 537 at 1:50,000, seven at 1:125,000, 19 at 1:250,000, eight IMW, 37 aeronautical charts, 41 indexes and 49 miscellaneous drawings.

The status of the 1:50,000 National Topographic Series stands at 29.8 per cent published or 3,995 maps of a potential 13,200 for all of Canada. In the 1:250,000 series only three remain to be published of a total of 918, and in the 1:500,000 series only five of 219 have not yet been converted from the 8-mile scale.

Map Reproduction Division

Map printing during the past year included 930 topographical maps, 399 air charts, 39 general maps, 511 departmental projects and 239 maps and charts for other departments, for a total of 2,118 maps and charts printed.

The Operational Research Unit received 52 projects during the year while six were carried over from 1968. Of these 54 were completed, 39 accepted, eight rejected, seven abandoned and four still in progress. The Division acquired a new color offset press and other new equipment. The metal foundry type was declared obsolete during the year.

Aeronautical Charts Division

The Division continued to produce up-dated aeronautical charts and related flight-information publications. New radar-surveillance charts were developed to assist air traffic controllers in their work, special charts of the Joint Arctic Weather Stations are being produced as aids to radar approaches, the series of 69 1:1,000,000-scale aeronautical charts is being redesigned to a series of 19 charts in the interest of better service, and the first edition of a *Manual of Criteria for Instrument Approach Procedures* was produced. In addition, significant extensions were made to the following series: Radar Surveillance Charts, Air Traffic Controller Charts and Maritime Plotting Charts.

Toponymy Division

During the 1969-70 fiscal year, the Division, in support of the Canadian Permanent Committee on Geographical Names, investigated 28,235 names of which 5,399 were new decisions. Besides names for new and revised maps, geographic nomenclature for 235 other maps was checked and verified. The staff answered 332 inquiries, entailing a significant amount of investigation and research.

A new edition of the Saskatchewan volume of the *Gazetteer of Canada* series was produced in 1969. The second edition of the New Brunswick volume is being prepared for publication.

The field-research program in New Brunswick was completed in 1969 and a study of the origins of names in that province is being written.

The Map Library answered 1,290 inquiries, loaned 969 maps, atlases and gazetteers to internal agencies and others concerned with map production and cartographic research, and acquired 6,819 new maps, 22 atlases and five gazetteers.

Almost 3,000 visitors were taken on tours of the Library's display areas, which illustrate new maps and new cartographic techniques.

The Canadian Permanent Committee on Geographical Names met in Toronto in 1969. The Secretary

participated in a meeting of the ad hoc group of experts on the Standardization of Geographical Names in New York in March 1970, and was appointed chairman of the section on maritime and underseas features.

BRANCH FUNCTIONS

Map Distribution Office

Distribution of maps and air charts to civilian clients rose 20 per cent for the year to a total of over 2,600,000 maps. This increase is in part due to more attention to public relations. Over 1,500 students, teachers and officials toured the Branch, illustrated talks were given at local schools, and booths staffed by qualified personnel occupied prominent positions at nine regional and sportsman's shows, mostly in Ontario. A publicity film and various brochures were prepared to widen this coverage in future. The Branch supplies 282 approved map dealers throughout the country and an attempt is made to visit each outlet at least once every two years to ensure that good service is maintained. Constant liaison is maintained with many map libraries. Revenue from map sales did not keep pace with distribution but increased 12 per cent to $515,000.

Three members of the Mapping and Charting Establishment, DND, were attached to the Map Distribution Office to handle Canadian Forces requirements which eased somewhat to a total of 980,000 maps.

Geography Division

This small unit is responsible for production of material for the fourth edition of the National Atlas of Canada and various related thematic maps. The atlas will comprise 128 sheets being prepared simultaneously in English and French. Most of the map work is well in hand and the remaining text material should proceed rapidly.

Several thematic maps were revised and about 40 new ones printed, including *Census Divisions of Canada, Population Density and Radio and T.V. Coverage.*

Automated Cartography

The study of applying computer technology to the graphical work of the Branch began in 1967 and was directed in particular to the major problem facing it, that of production and the systematic revision of the thousands of 1:50,000 maps included in its program. It was also realized that the system must be versatile enough to cope with occasional urgent orders for maps and to produce a wide range of special maps from the stored digital data.

The study had advanced sufficiently by the beginning of 1969 to decide the procedures and to write the specifications for the equipment required to undertake the three phases of digitizing the source material, of processing the digitized data in a computer and of plotting the processed data on an automatic drawing table. Contracts were placed for the specified equipment and in March 1970 a cartographic digitizer and a computer were delivered.

INTERDEPARTMENTAL COMMITTEE ON AIR SURVEYS

During the year, the Interdepartmental Committee on Air Surveys monitored aerial photography contracts in all provinces and territories to meet requirements from 16 federal departments and agencies.

Because of abnormally poor weather conditions a large number of contracts were not completed which will seriously affect the planned mapping program of the Branch.

Methods to increase the photographic coverage required to carry out the mapping program for the orderly development of the country will be attempted during the coming year, one of which is the use of a jet aircraft with the mobility and speed to follow favourable weather patterns.

TECHNICAL AID SECTION

The Surveys and Mapping Branch continued to support the Canadian International Development Agency (C.I.D.A.) by providing consultant and inspection services for surveys and mapping projects in Trinidad and Tobago, Guyana, Tanzania, Kenya and Barbados. On-the-job training was provided for technicians in aerial photographic processing and photo-mechanics. The third Surveys and Mapping Summer Course was held from the period May 20 to August 8 and a total of 47 students from 22 different countries received

practical instruction in survey and associated subjects. The summer course has proven to be a most effective way of providing practical survey training.

Meetings of the National Advisory Committee on Control Surveys and Mapping were held in Ottawa in May and October, 1969, and showed progress on studies of survey administration in Canada and of monumentation. The 11th annual meeting of federal and provincial survey officers was held in Toronto in September.

The third and last volume of Men and Meridians was published culminating a seven-year task by author D. W. Thomson on 300 years of surveying and mapping in Canada.

GEOLOGICAL SURVEY OF CANADA

The Geological Survey of Canada maintains a capability in mapping, detection, interpretation, research, and advice in geological sciences, including mineralogy and paleontology, and in complementary aspects of geophysics, geochemistry, physical geography and other disciplines. It co-ordinates these to provide a national and regional inventory of formations of rocks and surficial materials, their structures, minerals, landforms, and conditions of stability, and to develop concepts and techniques to maintain the standard of the inventory and to increase its usefulness and effectiveness in the exploration of resources and in contending with the physical environment.

The scientific work of the Branch is carried out by five divisions, one of which is centred in Calgary, and by centralized support services. During the report period the Branch had 489 active projects, of which 221 had a field component. Although most field projects were directed by permanent staff members some were led by university professors and post-doctoral fellows. Some studies, such as those carried out on the Pacific Continental Margin, were carried out under contract as were aeromagnetic surveys and some airborne geophysics developmental work.

Scientists of the Geological Survey were invited to assist in the investigation of lunar material brought back by the Apollo 11 astronauts. The samples of moon rocks were exhibited at the Geological Survey in October 1969, and nearly 25,000 people, including H.R.H. Prince Philip and Governor-General and Mrs. Michener, visited the display. Subsequent investigations at the Geological Survey were made to determine chemical composition, mineralogy, petrology, electrical conductivity, magnetic properties, isotopic abundance and age.

INVENTORY ACTIVITIES

This major phase of the work of the Geological Survey has been concerned with the description and explanation of Canada's main geological provinces, their rocks, structures, and mineral resources, and their magnetic, electrical and geochemical attributes. It also includes a systematic analysis and description of the landforms and surficial deposits resulting mainly from the advance and withdrawal of the great ice sheets that covered so much of Canada in relatively recent geological times. All these activities provide basic geological data to forecast, discover and evaluate our mineral resources, to provide scientific knowledge on the origin and development of the earth's crust beneath Canada, to provide an understanding of the physical environment, and for support of the administration and policy formulation in mineral and energy resources.

The various types of geological mapping are in support of inventory activities and involved the deployment of more than 100 field parties, a top priority being given to completion of a broad reconnaissance coverage of the unmapped parts of the country at scales of 1:250,000, 1:500,000 and 1:1,000,000. At the present rate of work it is expected that this phase will be completed in the mid-1970s. During the summer of 1969 approximately 140,000 square miles of bedrock were mapped at these scales. Some of the major accomplishments in the field were completion of the mapping of Southampton Island at the north end of Hudson Bay together with 20,000 square miles in Labrador and northern Quebec; continuation of "Operation Norman", a three-year regional study of the lower Mackenzie River area combining bedrock mapping, stratigraphic studies and Quaternary research; "Operation Stewart" almost completed mapping at a

scale of 1:250,000 of a 20,000-square-mile block in Yukon and Northwest Territories. "Operation Smoky" continued mapping in the northern Rocky Mountains with major emphasis on structural style and stratigraphic framework; a long term, multi-discipline investigation of the Mackenzie Delta and Beaufort Sea continued to provide basic data for the interpretation of the sedimentary column and for the evaluation of the petroleum possibilities of the region and also as a contribution to the basic understanding of the world's major deltas and their associated sedimentary basins.

Field work in the Arctic Islands included a reconnaissance of eastern Devon and southern Ellesmere Islands and a study of the stratigraphic and biostratigraphic relationships of upper Paleozoic rocks on northern Ellesmere and Axel Heiberg Islands. Investigation of the regional structural framework of the northern Mackenzie Mountains, the Franklin Mountains and the Interior Plains was continued, and similar studies were made in the southern Foothills, the northern Rockies and in northern Yukon Territory.

In addition to these operations in northern and relatively inaccessible areas involving varying degrees of aircraft support there were a number of bedrock studies related to inventory activities in all parts of Canada. Primary reconnaissance as a preliminary to 1:250,000 mapping was completed in the Great Northern Peninsula of Newfoundland; Cambro-Ordovician platformal rocks, with their petroleum and base-metal potential were studied on each side of the Strait of Belle Isle. Studies that contribute to the understanding of the Precambrian Shield, and in the evaluation of its mineral resource potential and in the control of the physical environment were undertaken, such as petrological investigation of previously unmapped Keweenawan lavas on Michipicoten Island, Ontario, and of the Archean rocks of Manitoba. In the western Cordillera and along the Pacific margin mapping and specialized studies on structure, origin, and geological development relate to the mineral deposits of the region as a basis for mineral exploration. Under contract with the Department of Geology, University of British Columbia, the Geological Survey supported a submarine geology program.

Geophysical surveys made significant contributions to the inventory aspect of the work of the Geological Survey. Existing contracts under the Federal-Provincial aeromagnetic survey program added 90,000 square miles of mapping, mainly in south-central Baffin Island and northern Quebec; however, bad flying weather delayed completion of the northern contracts. The Skyvan project produced airborne geochemical maps (U, K, and Th) covering 400 square miles near Bancroft, Ontario and a cross-country profile from Ottawa to Yellowknife and return which identified all known uraniferous localities en route and indicated several others. Preliminary results have been released on open file pending publication. These flights more than demonstrated the usefulness of the project which has aroused considerable interest in industry. Seismic surveys, both hammer and conventional, were made in Ontario, in Lakes Erie, Huron and Ontario, and in the Gulf of St. Lawrence and Strait of Belle Isle. Of these, the marine seismic surveys were of particular interest to oil companies concerned with offshore leases.

Economic geologists of the Branch continued their comprehensive studies of all aspects of the geology of specific economic elements or geologically coherent groups of such elements. Major reports dealing with titanium and iron were published and a mineral resources map and several metallogenic studies are well advanced. A Canada-wide compilation on nickel was completed and research continued on the primary alteration zones in the Cobalt silver deposits.

Research in Quaternary geology and geomorphology is directed towards providing information to assist in the planning, management and conservation of mineral, land and water resources, and of the natural environment. At present most of the scientific capacity is devoted to making a Canada-wide terrain inventory. The scale of these studies varies from broad reconnaissance in the north to detailed projects in heavily populated southern areas.

In the Goose Bay region of Labrador the first aircraft-supported survey of earth materials to be undertaken in northern forest regions was carried out to meet the requirements of the Newfoundland Forest Inventory-Land Capability group of the Department of Mines, Agriculture and Resources. A survey in the Mackenzie Delta and valley was accomplished to meet an urgent need for terrain and foundation information for possible pipeline construction in the Mackenzie transportation corridor. As part of the departmental program on pollution in the Great Lakes, Survey geologists carried out offshore sampling for information on sediment distribution and the organic and inorganic geochemistry of lake-bottom materials.

DEVELOPMENT ACTIVITIES

In support of its inventory role, the Survey must devote some of its resources to improving the methods by which it acquires its data; and to the development of new concepts, instrumentation and in the establishment of physical, chemical and paleontologic standards.

In geophysics, the development phase of the high-resolution magnetometer system was completed. The instrumentation, developed by Geological Survey staff, was installed in a specially modified Queen Air aircraft. It is the most advanced system of its type in the world and is a significant contribution towards maintaining Canada's leadership in airborne geophysical surveying techniques.

The National Aeronautical Establishment North Star aircraft, carrying similar high-resolution aeromagnetic instrumentation developed by NAE and GSC staff, obtained 11,000 line miles of magnetic data from low-level traverses across the Labrador Sea. Preliminary interpretation of these data suggest that sea-floor spreading occurred in Baffin Bay and the Labrador Sea at the same time that the North Atlantic Ocean was formed by the separation of Europe and North America, a movement that probably started 100 million years ago.

Tests of electromagnetic methods (AFMAG) for rapid airborne reconnaissance have continued and are proving to be a useful aid to geological interpretation especially where outcrops are sparse. AFMAG surveys were flown in Manitoba, Saskatchewan and Nova Scotia mainly in areas where the geology was fairly well understood, and many of the results, published during the year, show good correlation between the airborne data and the geology of the terrain. Other developmental projects include ground AC resistivity equipment and a new type of magnetometer which makes use of the Overhauser effect.

Development of geochemical methods of prospecting has continued and the first full scale helicopter-supported survey to test new prospecting methods for uranium was carried out in northern Saskatchewan. The year also saw the first successful trails of geochemical exploration techniques in permafrost terrain in the Coppermine area of the Northwest Territories.

The field analytical techniques developed by the Branch for geochemical surveys could well have application in environmental control with the increasing public concern over inorganic pollutants such as mercury, arsenic, selenium and other materials; new testing methods for mercury are under development and a report on its role in the natural environment was prepared during the year.

The establishment of standards of time and stratigraphic sequence is necessary for proper correlation of geological events in different parts of the country and for a proper understanding of the geological history of a region. Dating of rocks is achieved by physical methods and paleontological methods. Physical dating involving isotope measurements was carried out on hundreds of samples and further refinement of the potassium/argon method will be possible with the 15-inch solid-source mass spectrometer completed during the year. Fossils continued to provide the most readily applied means of dating and correlating Phanerozoic rocks both in the field and in the laboratory where paleontological specialists of the Survey identified thousands of specimens collected in the field; they also sampled and studied fossils in well cores, especially from wells drilled in the northern territories. From all these data standards of chronology, and stratigraphic sequence for the Phanerozoic sedimentary rocks of many parts of Canada were developed. Significant faunas were described and illustrated in published reports and many additional specimens were documented and added to the Survey's collections as permanent reference standards.

Petroleum geologists of the Survey, in collaboration with Geoservices of Paris, brought to near-completion a test of a surface prospecting method for petroleum using traces of hydrocarbons in soils. A computer file on oil and gas data in western Canada has been compiled; this study involves contributions from both compiled; this study involves contributions from both government and industry and should be of value in planning future uses of our oil resources and in outlining future petroleum provinces.

Much of the work on fossils and on studies directly related to petroleum was carried out at the Survey's Institute of Sedimentary and Petroleum Geology in Calgary. The Institute is also responsible for the custody of drill cores, samples and other data resulting from exploration by industry in Yukon Territory and

Northwest Territories and for drill samples from western and northern Canada. During the year more than 2,000 persons used the core- and sample- examination facilities.

During the report period, work in geomathematics and data processing continued with the objective of developing and applying electronic techniques to the handling of geological data, of providing a consultative service to staff members and of carrying out mathematical research on the quantitative definition and interpretation of geological problems, especially on mineral probability.

Many Branch engineering-geology studies contributed directly to the optimum utilization of Canada's physical environment. During the year such work has included the evaluation of factors that influence the engineering behaviour of geological materials in areas such as the Welland Canal and at damsites in northwestern Ontario, investigations in environmental geology, studies of the processes of landscape change involving slope movement, erosion, and frost action, both by field and laboratory studies, and the development of mineral exploration techniques using the unconsolidated "drift" as a prospecting medium.

SUPPORT ACTIVITIES

Apart from essential administrative and pooled technical services, the support activities of the Survey provide the link between the scientific programs and the user public.

The scientific results of the Survey's research are published in a variety of ways designed to best meet the users' needs. During the report period three memoirs, two economic geology reports and 13 bulletins were released. These constitute the comprehensive, terminal report series. In addition, 77 papers, nine preliminary maps, 23 colored maps (including those used to illustrate some of the preceding items) and 395 aeromagnetic maps were published. Staff members also published 161 papers in scientific journals, gave 97 addresses to scientific meetings and delivered 76 university lectures. In all more than 500,000 items were distributed through the Ottawa, Calgary and Vancouver publications distribution offices. The Branch also distributed 9,350 of its popular rock and mineral sets.

Libraries in Ottawa and Calgary continued to provide an essential service to the Branch and to the public. Circulation figures show that 55,000 loans were made, including many on inter-library loan to other institutions; 22,000 new items were added to the libraries which form Canada's largest collection of literature on the earth sciences.

In 1966 the Survey initiated a project to develop and co-ordinate the preparation of an index to geological data as a pilot study for a National Index. This study was completed during the report period and the 15 books of indexes were prepared for publication. Staff members from this project have since become part of the Canadian Centre for Geoscience Data.

Staff members acted as advisors and consultants to other federal agencies and to provincial governments. At the request of the Canadian International Development Agency geologists were sent overseas to provide technical advice on assistance programs. Many representatives of mining and exploration companies consulted with members of the professional staff. The Survey was able to offer a modest service to the general public in the identification of mineral specimens, and the various booklets for mineral collectors continued to be best sellers.

The Geological Survey provides secretariat and funds for the National Advisory Committee on Research in the Geological Sciences of which the director of the Survey is permanent chairman. In 1969-70 a total of $275,240 was disbursed as grants-in-aid to Canadian universities. The National Advisory Committee also sponsored a conference on research in tectonics at the University of Manitoba and jointly sponsored with the Survey the publication of three volumes of proceedings of earlier symposia.

MINES BRANCH

The Mines Branch is a complex of laboratories and pilot plants designed to assist the Canadian mineral industry in the more efficient extraction and elaboration of mineral wealth of all types, and to improve and broaden the uses of metals and minerals. Particular emphasis is placed on the elimination of waste in mineral production, reduction of air pollution in industry, reduction of corrosion, mine safety, the discovery of new methods for working with low-grade or hard-to-process minerals and ores, and similar factors that will benefit the Canadian public and Canadian industry in its efforts to remain competitive in world markets.

The work is carried on in seven divisions, or centres: Physical Metallurgy, Fuels Research, Mining Research, Mineral Sciences, Extraction Metallurgy, Metals Reduction and Energy, Mineral Processing. There is a Technical Services Division which serves the other divisions by building or installing instruments and equipment, and a branch library.

The Physical Metallurgy Division concerns itself with the casting and solidification of metals, forming and fabrication, evaluation of engineering and other properties, experimentation with new alloys, and computerization of metallurgical processes. Division experts also dispense advice to Canadian industry and undertake tests and investigations on behalf of the latter.

The Fuels Research Centre seeks to find better ways for using and conserving Canada's fossil fuels—coal, petroleum, and natural gas. Special attention has lately been paid to combustion that will reduce air pollution. The refining of low-grade oils continues to receive considerable attention, as does the conversion of Canadian coals into metallurgical cokes.

The Mining Research Centre is concerned with rock breakage at mines by drilling, blasting, crushing and grinding, and stability of rock around mine excavations. It seeks to improve the design of open pit mines. Work is being carried out on the elimination of health hazards in mines and on more effective mine management.

In Mineral Sciences, the emphasis is in the scientific study of ore minerals, such as sulphides, the properties of complex minerals, standards for categorizing minerals, and analytical work for both the Mines Branch and for outside clients.

In the Extraction Metallurgy Division, research is carried out on pollution abatement in mine effluents, hydrometallurgy, and the causes and control of metal corrosion. Studies are also being carried out on the kinetics and thermodynamics of various important metallurgical reactions.

The staff of the Metals Reduction and Energy Centre studies the energy requirements of Canadian metals and minerals producers, transportation problems incidental thereto, carries out research on the application of energy to metallurgical processes and prevention of air pollution in metallurgy, and disseminates results by various organizational means.

In Mineral Processing, research is carried on in aid of mining, the production of ceramics and construction materials, and advice is given on various problems to private industry and the government. Aid to mining consists chiefly in finding better ways of concentrating ores.

Details of these and other activities will be found in the sections that follow.

PHYSICAL METALLURGY

The work of the Physical Metallurgy Division consists essentially of applied research and development related to the conservation, processing, properties and utilization of Canada's metals and the fabrication of products from these metals. It is designed to provide the maximum assistance possible to the Canadian economy in general, and to the metallurgical and resources industries in particular.

Research is based on an assessment of present and future requirements for continued technological growth, and in particular, on the necessity of filling gaps in the knowledge of metals science and technology. The comprehensive, interlocking metallurgical facilities available in the Physical Metallurgy Division enables a wide range of activities to be considered. Emphasis is on applied research and development that needs pilot-plant scale melting, casting, forming and fabricating facilities.

The Division also undertakes work to satisfy the needs of other government agencies, such as the Departments of National Defence, Public Works and Transport.

Work on metals and alloys processing and utilization is divided into five research-and-development activities and one consulting-and-investigations activity. The research-and-development activities are casting and solidification, forming and fabrication, engineering properties and service evaluation, alloy metallurgy, and techniques and equipment for research and development.

Casting and Solidification

Research on the direct quantitative determination of oxygen in molten metals by electromotive-force measurements has culminated in a successful commercial development known as the Leigh Oxygen Probe System for use in steel plants. This is an outstanding example of a successful mission-oriented research project initiated in this Division. It has been carried through successive stages of field trials and product development by the co-operative efforts of this Division, the Canadian steelmaking industry and Leigh Instruments Limited who are manufacturing and marketing the Leigh Oxygen Probe System on what is rapidly becoming a world-wide scale.

A ciné-radiographic installation using an X-ray intensification system has been used during the past year to study the flow of molten steel in moulds. This work is in its preliminary stages and is already providing significant information on the design of sprue and gating systems.

Forming and Fabrication

The compacting and sintering characteristics of various grades of nickel powders produced by Sherritt Gordon Mines Limited are being studied. Work has also been started on a study of the relationship between the characteristics of iron powders from various Canadian sources, and their compacting and sintering behaviour. The samples are representative of different methods used in iron-powder production in Canada. This work will enable fabrication processes to be adapted and modified to use these Canadian powders.

A study has been initiated on the effect of plate configuration on heat flow during welding. At present, fillet joints and double-vee butt joints are being studied. Data indicate that the simple assumptions used in the controlled thermo-severity test are not accurate, suggesting that some modifications may be necessary.

Engineering Properties and Service Evaluation

A study of the configuration of the fracture surfaces of both tensile and crack-notch toughness specimens has shown that the "shear lip" (slant fracture) configuration of these surfaces in not a result of shear, but is rather characterized by purely normal displacements and zero shear. This study has led to the hypothesis of a stress-distribution relationship that can account in quite a precise and invariant way for the form of the fracture even when plastic flow of several per cent preceded fracture. This relationship has been experimentally checked in the laboratory in a number of cases.

Studies of the environmental cracking of ultra-high-strength alloys have indicated that for HY 140 and 18 per cent nickel (250) maraging steels in sea-water service, cathodic protection of highly stressed members might be dangerous. Studies are also under way to determine the differences in the mechanism of stress-corrosion cracking and hydrogen-embrittlement cracking for maraging steels.

Alloy Metallurgy

Alloy-metallurgy research is in progress on a variety of steels and also on titanium, aluminum, magnesium, copper and zinc alloys.

In order to promote the use of Canadian molybdenum, the effect of molybdenum additions to austenitic chromium-nickel stainless steels is being evaluated. The effect of alloying elements on the corrosion behaviour of AISI Type 430 stainless steels is being studied. Low-carbon martensitic stainless maraging steel compositions employing beryllium as the age-hardening ingredient are being investigated.

Research has been initiated to investigate ways of improving the very low ductility of titanium alloys containing more than 7 per cent (in weight) of aluminum. The metallurgical factors affecting environmental cracking behaviour of titanium alloys in sea water are being evaluated.

The structure and properties of the heat-affected zone of welded joints in the Ti-6A1-2Nb-1Ta-1Mo alloy

are being studied. The use of the pulsed-arc welding process for the out-of-chamber welding of this alloy is also being evaluated.

Research on zinc-base aluminum alloys is continuing. The phenomenon of room-temperature ageing encountered in these alloys is being studied and the reasons are being sought for the superior impact strength of wrought zinc-aluminum alloys as compared with die-cast alloys of similar composition.

Techniques and Equipment for Research and Development

Considerable effort is being devoted to the establishment of computer programs for the correction of raw data produced by the electron microprobe analyzer. Uncorrected data may often lead to serious errors in interpretation. Facilities are also being developed to produce homogeneous standards of known composition that may be used to calibrate the electron microprobe analyzer.

Research has been initiated to develop new techniques and applications of the scanning electron microscope. Included in this project will be studies on image and contrast characteristics as a function of the material under examination, and the utilization of the generated outputs for quantitative metallographic purposes.

Consulting and Investigations

During the past year this Division has conducted 20 metallurgical investigations for as many Canadian manufacturing industries. It has also carried out 30 metallurgical investigations for 14 Government agencies. In addition to these investigations, this Division has supplied information and advice in response to 104 inquiries received from 84 Canadian manufacturing industries and 146 inquiries received from 28 Government agencies.

The metallurgical investigation of components from the HMCS *Kootenay* gear box was instrumental in identifying the cause of the fire which occurred aboard that ship.

A complete metallurgical investigation has been conducted on the cracked foil of the FHE 400 hydrofoil vessel. Reasons for the occurrence of this cracking have been clarified as a result of this investigation, and recommendations have been made to the Department of National Defence and its contractors, indicating how the recurrence of this type of failure might be avoided.

At the request of the St. Lawrence Seaway Authority, an investigation was undertaken to develop an appropriate welding procedure to rebuild by welding the worn surfaces of the tracks of a rolling lift bridge, on the Welland Canal. A welding procedure suitable for this application was developed.

Investigations have been carried out on the cold rolling of nickel plate for the Royal Canadian Mint, in order to provide a basis for the selection of rolling-mill equipment by the Mint.

Written examinations for the certification of industrial radiographers were conducted at 14 centres across Canada during this current year; 222 junior applicants and 95 senior applicants were certified. Applicants who undertook the practical tests at the Physical Metallurgy Division numbered 28.

Two ten-day courses in radiography were given to DND Quality Assurance Branch inspectors, and a four-day series of lectures on non-destructive testing and on welding and corrosion was given to 14 steamship-boiler inspectors from the Department of Transport.

FUELS RESEARCH

The Fuels Research Centre is the agency of the Federal Government concerned with the development of new engineering and scientific approaches to encourage the efficient utilization and conservation of Canada's coal, petroleum, and natural gas resources. These fossil fuels play a dominant role in Canada's economy and yet their use inevitably gives rise to some pollution of the environment. The Fuels Research Centre has shared the public interest in and concern for the efficient use and development of the fossil-fuel resources, particularly as such utilization influences the quality of the atmosphere. Public awareness of the seriousness of the pollution problems is now finding expression in terms of legislation the world over.

The enactment of legislation and the establishment of limits and penalties is one thing; but to overcome the technical difficulties to achieve these desired limits without suffering severe economic penalties is a much more complex problem. It is in this area that the

Fuels Research Centre has attempted to assist industry by finding practical solutions to some of the atmospheric pollution problems arising from combustion. This program will require continuous effort into the foreseeable future, as each advance in technology will be offset by two factors which tend to increase atmospheric pollution, the growth in population and the migration of people to the major centres in search of employment in industry.

To concentrate the research of the Fuels Research Centre on major national needs in a manner that would permit better financial support and control, the Centre's research was reorganized in October 1969 into three basic programs: air pollution and combustion research; the evaluation of the quality of Canadian fossil-fuel resources; and a program which includes the certification of electrical and diesel equipment for use in coal mines, and the associated research on combustion and ignition of gases and dusts.

During the year progress in all programs was impeded by the relocation of all facilities of the Centre to the new site near Bells Corners, Ontario, 12 miles from Ottawa. At the close of the calendar year, a considerable amount of reconstruction of the pilot plants remained to be completed. This included the 18-inch movable-wall test oven for the Metals Reduction Group, and all the large pilot plants of the petroleum-processing and high-pressure-hydrogenation groups. Every effort was made within the existing budget to complete as much of the construction as possible before the end of the fiscal year. This relocation, though expensive and time-consuming, will lead to improved operations.

Conceptually the program dealing with air pollution and combustion research may be divided into a) those projects concerned with the improvement of the combustion process and the elimination of pollutants after combustion by dispersion into the atmosphere, and b) those projects concerned with the elimination of sulphur from the fuel and the improvement of fuel quality before combustion.

In the first class the emphasis has been on a co-operative study o fthe dispersion of smoke plumes from the stacks of major thermal power plants in operative study of the dispersion of smoke plumes and Resource Management, and the meteorological service of the Department of Transport, which seeks to analyze in a quantitative manner the movement of air into and out of major urban centres. During the year the analytical instrumentation for use in helicopters was tested. The results were encouraging, so that further studies were planned for 1970 with superior range-finding equipment to define the position of the air samples with greater precision.

The Riley turbo furnace was reconstructed and combustion studies on lignite were completed to provide a basis for boiler design using this class of coal for the generation of thermal power.

The combustion research concerned with the way combustion pollutants spread through the air has been held up pending the assembly of the controlled-history furnace, and the acquisition of equipment.

Considerable effort was made to develop a satisfactory thermal method for the disposal of government stocks of DDT. Preliminary experiments indicate that a satisfactory combustion method of destruction can be developed by employing a blue-flame burner and a suitable system for scrubbing the hydrochloric acid from the combustion gases. A research report will be available shortly to enable the Department of Agriculture and others to build and operate similar equipment.

The elimination of sulphur from oils prior to combustion falls into two categories — the elimination of sulphur from residual oil obtained after the distillation of a normal crude oil, and the removal of sulphur from low-grade heavy crude oils such as the Athabasca bitument. With the development of increasingly stringent air-pollution regulations the markets available to both these types of oil will become more and more restricted. On the other hand the economy can only be sustained by an abundant supply of cheap energy from these sources. New technology has to be developed to eliminate sulphur from these fuels at reasonable cost. The core of the high-pressure hydrogenation research is directed to this objective.

Considerable progress was made during the year in understanding the advantages and limitations of the thermal hydrogenation of Athabasca bitumen. The refining conditions under which there was a slow accumulation of polymer in various parts of the hydrogenation system were outlined in a scientific paper presented in Edmonton. This information has been of

considerable interest to those in the industry concerned with the refining of this class of heavy crude oil and it will provide a basis for comparison with future catalytic experiments planned in the combined liquid-and-vapour-phase pilot plant.

The continuing tension in the Middle East together with shortages of natural gas and cheap sources of petroleum in the United States has spurred the interest in developing Arctic sources of petroleum as well as a review of North American fossil-fuel resources. The Fuels Research Centre is particularly concerned with the evaluation of the quality of the Canadian portion of these reserves and the development of improved techniques for obtaining sulphur-free petroleum from low-grade oil sands.

A directory of Canadian oil-analysis and reservoir data has been published. This directory includes most of the crude-oil analyses performed over the years at the Fuels Research Centre and is fairly representative of all significant Canadian oil fields. A project is now under way which will permit these data to be sorted mechanically by physical property.

Much of the pollution that arises from the combustion of low-grade petroleum is due to sulphur. The only method of effectively removing this element and producing a stable hydrocarbon is to remove the sulphur from the oil with hydrogen. At present little is known of the chemistry of the sulphur compounds that occur in the gas-oil distillation range. A project was therefore initiated early in the year to fractionate the sulphur-containing compounds by using gas chromatography. Significant advances were made.

The development of analytical capability is an important part of the research on petroleum, for the benefits are felt in a wide variety of problems extending from resource evaluation to the identification of oil in major marine oil spills such as that of the "Arrow".

One of the problems in the evaluation of western Canadian coking coals for export to the Japanese market is that the coke quality is underestimated by the method currently used and developed to assess the quality of Appalachian coals. Progress was made in rectifying this underestimation.

Another concern of western Canadian coking coal industry is the loss of coking properties that occurs through oxidation during mining, processing, transportation and storage. A study of the mechanism of the oxidation has tracked down the main chemical reaction causing this deterioration.

The demand on the Canadian Explosives Atmospheres Laboratory for the certification of electrical equipment used in mines and industrial areas where combustible gases are present increased substantially during the year. The demand for the certification of diesel engines for use in mines is also growing with the increased mining activity in western Canada.

The research conducted by the laboratory has involved the transmission of explosions through metal joints and cylindrical channels, as well as the investigation of spark incendivity. Recent work has demonstrated the hazard associated with the use of aluminum castings. Fine particles of aluminum in the joints greatly increase the chance of transmission of an explosion.

MINING RESEARCH

The Mining Research Centre during the past year continued to decentralize its staff by setting up a Western Office in Calgary (sharing space with the Institute of Sedimentary and Petroleum Geology). More staff is now located outside of Ottawa, at the Elliot Lake Laboratory and the Western Office, than in Ottawa at the Canadian Explosives Research Laboratory and the Rock Mechanics Laboratory. However, the actual work, which is done substantially in cooperation with mining companies, is spread throughout the country. The establishment of the Western Office will make it easier to work with the western coal, base-metals and potash mines.

The Centre operates on the project system, many individual projects being integrated with the work of individual companies and universities. Wherever possible, the prospect of an attractive payoff is used in the selection of projects. Those projects on which the potential benefit-cost ratio is particularly high receive maximum concentration of the budgetary resources.

Rock Breakage

The breaking of rock both at the mining face and subsequently in reducing the large blocks of ore to a fine size suitable for processing is a major part of mining. One objective of this research is to explore the mechanics of breakage, using forms of energy other

than explosives that may lead to radically new mining methods. This is a pioneering activity undertaken at the request of the Mining Association of Canada as a result of a survey showing that their members believe rock breakage is one of the most important areas in which research should be able to effect savings.

Besides helping to make current systems more efficient through the discovery of novel methods of drilling, blasting, crushing and grinding, it was also envisaged that conventional operations may be telescoped into some combined procedure quite unlike current practices. The work is being done primarily at the Elliot Lake Laboratory.

Blasting research is also being pursued to increase safety and to reduce the cost of drilling and blasting in industry, which accounts for the expenditure of approximately $100,000,000 per year in Canada. By the application of analytical techniques it should be possible to produce significant savings within a reasonable period of time. The resources of the Canadian Explosives Research Laboratory, the Rock Mechanics Laboratory and the Elliot Lake Laboratory, together with those of some private companies, are all being used for this work.

Ground Control

How to ensure stability of the rock around a mining excavation — that is, ground control — is an important aspect of mining. Solutions of the problem are being sought through analytical methods, which have been used in the design of building structures for over a hundred years. However, considerable research is necessary, both because of the great complexity of mining openings in Canada and because adoption of the large safety factors common in structural design might seriously impede economic extraction.

The work is done mainly through the Elliot Lake Laboratory with mining companies from Newfoundland to British Columbia. Control of the weak and friable roof rocks in both the eastern and western coal fields is being studied with various companies. Work is being done in the Saskatchewan potash mines and Ontario salt mines. In the former case, little experience exists in the world for mining such materials at the depths of these deposits. Studies have been made for the design of layouts for new mining methods in the uranium mines. Much information has been gathered from underground measurements in base-metal mines in both Quebec and Ontario on the stability of pillars. Design procedures have been evolved for support with rock bolts; work is proceeding to achieve the same objective for filling with waste mill tailings. Canada has one of the largest underground mining industries in the world, and such studies are extremely important to the Canadian economy.

As over 50 per cent of the ore produced in Canada comes from open pits, a substantial part of the research budget of the Centre is applied to open-pit mining. To produce the 200,000,000 tons of ore from these mines, typically 250,000,000 tons of waste rock must also be excavated from the slopes required for these pits, which can be as deep as 1,000 feet. The economic feasibility of any potential open pit is, therefore, largely dependent on the slope to which the walls must be cut. Scientifically determined optimum pit slopes would be worth much to industry. Individual mines, however, do not have adequate incentive to engage in the comprehensive program required for such a technological advance, and government enterprise is required.

Computer simulation of open-pit slopes is being used to examine the basic factors influencing the stability of slopes in rock. Under study are stress distributions in typical slopes subjected to varying tectonic stresses together with deformation patterns and their correlation with known modes of failure. In addition, optimization of excavations is being sought by changing slope angles as the mine gets deeper.

Environmental Control

Research is being conducted towards improving the environmental conditions in mining. Whereas the physiological effects are the concern of other research groups and ventilation design is done by mine staffs, the physics of measuring environmental conditions requires the more detailed study that is being undertaken in this program. At the present time, research on the standardization of methods for measuring dust and radiation hazards is being conducted in close co-operation with the Mine Accident Prevention Associations of Ontario and Quebec as well as with individual companies experiencing critical problems. Although conditions in Canadian mines are generally good, improvements must be made constantly in the working environment (e.g. air-conditioning, humidity control, noise suppression, and good lighting) to ensure

continuous interest on the part of technical personnel and labour in working in the mines. The work is being done primarily in the Elliot Lake Laboratory.

Mine Systems Engineering

Work has been started on systems analyses of various mining operations. Advances that are made by physical research on the various phases of operations (drilling and blasting, ground control, transportation, etc.) are being examined to determine their influences on mine economics. Computer programs are being developed for use by company staffs on mining properties.

With the high degree of complexity of current technology, we find that no organizations exist in the country with the personnel and facilities capable of assisting those with problems in many specialized areas. Consequently, calibration, testing and advisory services are provided when required by companies and agencies in the mineral and associated industries. This is consistent with the Mines Branch policy of orienting its research to fill gaps in technology of particular concern to the country. At present, most of the work is being performed at the Canadian Explosives Research Laboratory.

The general function of communication is being expanded by the development of an Information Centre involving both the Mines Branch Library and the Elliot Lake Laboratory whereby, through information officers and telex links, it is planned to provide industry and the universities with assistance in finding and obtaining the latest research information on any subject. At present, integration with private research is achieved either through joint projects or through liaison on subjects of mutual concern. The companies co-operating with the Mines Branch in research produce approximately 75 per cent of the Canadian mining output. Besides the conventional method of publishing significant results in journals, interim reports are written. Some of these are distributed exclusively through the Mining Association of Canada to interested companies, while others are used as research notes that are exchanged with laboratories both in Canada and abroad.

Canadian Advisory Committee on Rock Mechanics

In 1963, the Canadian Advisory Committee on Rock Mechanics was formed to stimulate greater interest in this base science for mining and to co-ordinate research. The membership has consisted primarily of representatives of industry and of the universities, with Mines Branch personnel providing the secretariat.

During the past year, one of the Committee's specialist panels completed a study of the requirements for improving design and construction practices of waste embankment. It is recommended that the Mines Branch have a code of practice compiled so that such disasters as Aberfan and the Crows Nest slide can be avoided in the future.

One of the principal ways in which the Mines Branch, with advice from the Committee, has been able to stimulate research is through its grants-in-aid which, starting with $10,000 in 1962, have grown to a cumulative total of $363,000 for mining research. The Committee also periodically examines and appraises the research of the Centre in rock mechanics.

MINERAL SCIENCES

Research in the mineral sciences has as its objective the provision of a sound, scientific base for the development of new technology in the extraction, processing and utilization of Canada's mineral resources. In working towards this objective, the Mineral Sciences Division employs a multi-disciplinary approach, utilizing the tools of chemistry, physics, crystallography and mineralogy in the planning and performance of research. The different research and development activities of the Division are broadly categorized into three core programs: the Sulphide Program, the Materials Research Program, and the Analytical Research and Services Program.

Sulphide Program

The Sulphide Program is designed to make use of new scientific concepts and techniques in the study of ore minerals (mainly base-metal sulphides which account for such a large portion of Canada's mineral production) with the purpose of tailoring practices used in the recovery of minerals and metals to the intrinsic characteristics of the ore minerals. Projects under this heading are classified into three sub-groupings: characterization of the minerals (relating the internal composition and structure of minerals to their bulk properties); studies of mineral assemblages, to improve the treatment processes used in beneficiation; and studies of the pro-

perties and phenomena that are associated with mineral surfaces, which are of particular importance in controlling the mineral separation process.

An essential part of this program has been the production of laboratory-grown crystals of mineral compositions. Success has been achieved in growing a number of sulphides of iron, nickel, and cobalt, as well as arsenides and sulfarsenides of these metals that have certain structural features of common interest to the program. Methods used in the growth of the crystals have been of three types — vapor-phase transport, using iodine and bromine; flux-melt techniques; and hydrothermal methods. Considerable data have been accumulated on the mechanisms and chemistry of crystal growth that will provide a sound basis for future progress. Copper sulphides were the subject of particular attention, leading to the discovery of a new variant of valleriite, a hydro-copper-iron sulphide, and to further progress on the characterization of talnakhite, a recently discovered copper-iron sulphide. Chemical bonding in minerals of the pyrite structural group was investigated by combining the results of micro-hardness and infrared determinations and applying thermodynamic considerations. The electrode behaviour of some semi-conducting sulphides was studied to explore the relationship between electrical properties of the minerals and their electro-chemical behaviour. Research was carried out to establish the nature and properties of metal complexes formed with sulphur-bonding chelating agents, in which it was necessary to synthesize the materials to be studied.

Studies of assemblages of ore minerals that are characteristic of Canada's economically important deposits are undertaken to provide basic mineralogical data, such as the identity of the mineral constituents, mineral compositions, and the distribution of constituents. This type of study is done primarily to examine and identify the important mineralogical features that influence exploitation and beneficiation of ores. Attention is given chiefly to mineral districts that have some special economic significance. Currently, for instance, work has just been completed on a detailed study of the Cobalt district where operators have had great difficulties in the past owing to the small size of orebodies and the mineralogical complexity of the ores. In the course of this work 13 operating mines were visited to collect samples and examine working faces; samples were collected from 46 other dormant properties to obtain as complete a picture as possible of the mineralogy of the Cobalt ores. New information and a better understanding of the nature of these silver ores has resulted in modifications to operating procedures in the recovery of silver and in day-to-day ore development. Two similar studies have been started during the past year; one in the Red Lake district of Ontario where significant base-metal deposits have recently been discovered, and the other in the disseminated copper deposits of the Highland Valley, British Columbia. A basic understanding is being sought of the electrochemical and surface properties of minerals in contact with aqueous electrolyte solutions, especially of the electrical double layer formed at the mineral/solution interface. This, in turn will clarify how these properties are influenced by physical or chemical treatments of the minerals or of the mineral/solution system. The double layer is being examined, for oxide as well as sulphide minerals, by various techniques including potentiometric titrations, Zeta potential measurements, electrophoretic measurements, and radiotracer methods. Research was begun into the possibility of altering mineral-surface properties by the use of high-intensity radiation to give either a higher flotation yield or greater flotation selectivity.

Materials Research Program

The concept of materials research is of rather recent origin. In brief, it is concerned with the relation between the structure and properties of materials, with factors which control the internal structure of solids, and with processes for altering the structure and properties of solids. Because of the tremendous number and variety of materials in existence it is necessarily a broad field of study. The Mineral Sciences Division is concerned only with a very small part of it, for which capabilities exist in the Division and which is related directly or indirectly to mineral processing and utilization.

Three activities constitute the Materials Research Program: phase-equilibrium studies on oxide systems, development of synthetic magnetic materials (ferrites), and a characterization program in co-operation with the Organization for Economic Co-operation and Development (OECD), an international co-operative project.

Work on phase equilibrium in oxide systems is of use in ceramics, cement manufacture, refractory brick production, and in other applications where the behaviour, or durability, of materials is critically dependent upon

composition and temperature ranges. With recently increased abilities to go to higher temperatures in phase-equilibrium studies, work was activated on the system CaO-Al_2O_3-Fe_2O_3, which involved reactions that take place in cement clinker production; and on the system MgO-CaO-Fe_2O_3-SiO_2 because of some unsolved problems involved in the performance of chrome-magnesite refractory bricks. New work was started on the system Sn-O because of the interest in tin oxide materials in electronic applications. Studies of three other systems were completed with the publication of results: Ti-O, CaO-Ta_2O_5-SiO_2, and CaO-Nb_2O_5-TiO_2-SiO_2.

Ferrites are used as magnetic materials for both the permanent and non-permanent types, which find their main application in the manufacture of television sets and computers. Use of these materials has greatly multiplied during the past few years, and projected trends indicate greatly increased markets for Canadian production. Past work of the Division has been concentrated on the hard ferrites, the permanent-magnet variety, with more recent attention being given to the soft ferrites. Canada has abundant resources for the production of both types and a large amount of assistance has been given industrial companies on various aspects of ferrite technology. Strontium is an important constituent of hard ferrites, and as a large body of celestite (strontium sulphate) is under development in Nova Scotia, research was undertaken to devise methods of extracting the strontium in a form suitable for the production of ferrite materials. Two methods were examined and successfully adapted at bench scale for this purpose.

The characterization program is a co-operative program jointly undertaken with about 60 other laboratories in different countries that are all participating in the Organization for Economic Co-operation and Development. The purpose is to examine and characterize very pure materials by a number of methods, e.g., spectroscopy, electronic behaviour, structural defects, etc.

Analytical Research and Services

The research of the Mines Branch requires the identification and measurement of a large number of chemical and physical factors, which is done in the Mineral Sciences Division. Most of this is done by chemical procedures, but a substantial amount of mineralogical examinations, X-ray analyses, magnetic and electrical measurements, and optical examinations are aslo made. As a result, an appreciable amount of work of the Division is devoted to developing new techniques and improving existing ones for use in the examination and measurement of mineral and material properties, including chemical analyses. The establishment of standard methods of analyses and the provision of standard reference materials are part of this general program.

The Mines Branch has a heavy commitment to supply standard reference materials for metals, minerals, and ores. These are used in Canadian laboratories particularly, and also by organizations throughout the world. Work leading towards the certification of standard platinum metal ores and concentrates has been just about completed, and new projects have been started on supplying standard reference materials for iron, radioactive ores, and six different sulphide ores from Canadian deposits, covering the important base metals.

Methods of chemical analyses are under continuing examination for ways of improving both accuracy and speed of analysis. Recent examples include the development of X-ray fluorescence methods for determination of tungsten and strontium in their ores, determination of fluorine and silicon in ores by neutron activation, installation of a new direct-reading vacuum spectrometer to obtain rapid and close compositional control of metal and alloy products made in the Physical Metallurgy Division, and an examination of some of the problems encountered in on-stream X-ray fluorescence analyses of ore slurries. Other applications of instrumentation to analytical procedures that have been made recently are: the use of Mössbauer spectroscopy to provide knowledge on the valence state of some atoms which has proved useful in slag chemistry, and the use of optical absorption for determining the nickel and iron content in a number of silicate materials.

Work in crystallography covers everything from simple identification of minerals by powder diffraction methods to the complete solution of crystal structures. A large part of the recent effort has gone into the modification and additions to the computer-controlled diffractometer system, which is now operating on a routine basis gathering data for use in the determination of the crystal structures. The system, with the aid of magnetic discs as back-up storage, is now able to exchange programs, and perform all operations of alignment and data col-

lection automatically. The data, which will shortly be gathered on magnetic tape, are then processed on a much larger computer, with the X-ray 67 program system. The programs for statistical phasing of crystal structure data have been written in this laboratory and are in general use in crystallographic laboratories throughout the world.

A feasibility study has been completed into the application of neutro activation analysis in the field of copper in drill core, and the determination of copper values for grade control in mining operations. Three neutron sources were used: californium 252, antimony 124/beryllium and a neutron generator. The neutron generator gave significantly better sensitivity than the other two neutron sources and could provide a rapid method for copper determinations.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, research and development were carried out on pollution abatement, on hydrometallurgical processes, and on causes and control of metal corrosion. Studies were also made of the kinetics and thermodynamics of various metallurgical reactions of importance in these fields. The results were made freely available to the Canadian mining and metallurgical industry in Mines Branch reports and published papers, through co-operative organizations such as the Canadian Mineral Processors, Canadian Mineral Analysts and the Canadian Uranium Producers' Metallurgical Committee, and through informal direct contacts.

In view of the concern over pollution such as might result from mining and metallurgical operations, increased effort was directed toward developing new and more effective pollution-control techniques and to promoting the efficiency of existing technology. Surveys of pertinent literature were made and circulated to the industry. Techniques for removal of undesirable metals from effluent solutions from base-metal operations, such as by absorption on activated carbon or ion-exchange resins, were investigated. In gold mining, the presence of even traces of cyanides in plant effluents is undesirable, and more effective analytical procedures were developed for the determination of small amounts of these compounds. The causes of arsine release during gold precipitation were also investigated.

As part of long-term studies to avoid sulphur-dioxide pollution of the atmosphere by pyrometallurgical plants treating sulphide-bearing ores, an alternative hydrometallurgical approach based on a chloridizing technique was studied. In this approach the sulphide sulphur is converted to hydrogen sulphide and then to elemental sulphur.

The conventional techniques for controlling sulphur-dioxide emission from electricity-generating plants using sulphur-bearing fuels by the injection of powdered limestone into the system are relatively inefficient both in sulphur-dioxide removal and in limestone utilization. To provide a basis for improving these techniques, the chemistry of the reactions between sulphur dioxide, oxygen and limestone was studied in detail to develop reaction criteria. Also a procedure for evaluating the effectiveness of different limestones for sulphur-dioxide absorption was worked out.

In the field of hydrometallurgy, naturally occurring bacterial leaching of uranium ore left underground in the Elliot Lake area stopes suggested the possibility of direct leaching of full stopes of freshly mined ore, thus substantially decreasing the amount of ore that must be brought to surface. To explore this possibility, column-leaching reactors were set up in the Mines Branch pilot plant in which run-of-mine uranium ore was contacted by percolation with bacterially active leaching solutions for extended periods. Preliminary results indicated that acceptable extraction of uranium can be obtained on both coarse and fine ore, and under suitable mining conditions the technique may well offer a more economic way of mining marginal uranium ore deposits.

In Canada there are a number of occurrences of copper and nickel sulphide ore that do not respond well to conventional concentration processes and are unsuitable for treatment by conventional ore-smelting technology, particularly in view of the current requirements for control of air and water pollution. As a way to overcome these difficulties, acid pressure-leaching was investigated, since with suitable conditions most of the sulphides can be converted to inert elemental sulphur. Acid pressure-leach investigations on a copper-nickel-iron sulphide material showed that pentlandite can be decomposed under moderate conditions to produce nickel in solution and elemental sulphur. However, further development work is required to obtain a satisfactory process for ores containing chalcopyrite.

The application of solvent extraction for the separation of nickel and cobalt in acid solutions was studied and a successful technique developed whereby a solution

with cobalt and nickel in the ratio of 1:3 was converted to a solution with a cobalt-to-nickel ratio of 500:1. Since this ratio is acceptable for a final product, the technique is being adopted in industry. In other work, a solvent extraction method was developed that could be used on alkaline solution systems for the separation of copper, nickel and cobalt, in place of the complex conventional processes now in use.

A long-term program has been carried out on the prevention of metal corrosion in mining and other industries. In the past year surveys were made to examine the common causes of corrosion in mining, and advice and background information in ways to avoid such damage have been provided to the industry. Corrosion is often the result of exposure to acidic industrial atmospheres, and improved chemical protection coatings for steels have been developed to prevent such attack.

Electroplating studies were continued and of particular interest has been the development of improved chromium plating baths with a low chromium-to-sulphate ratio. The improved bath composition, in which sodium hydroxide is added, permits good operation. These baths have a high plating rate and the coatings provide better protection for steel than those from conventional baths.

Parallel with the process research, studies were made of the kinetics and thermodynamics of related metallurgical reactions. Controlling factors in heap-leaching of copper minerals were investigated on a laboratory scale. The thermodynamic data of the cuprous oxide-cuprous sulphide system which is important in copper smelting were found to be unreliable, so studies were undertaken, utilizing an automated data-gathering system, to obtain experimental results that could be satisfactorily correlated. Another project has been devoted to the resolving of factors affecting the cementation of copper on aluminum sheet. Work was continued on the sulphation, oxidation and sintering of cobaltous oxide, in connection with its potential use as a catalyst for sulphur-dioxide removal.

In support of the various research activities in the Division, techniques used in the analysis of ores and metallurgical materials were modified and improved. A new Jarrell-Ash fully-compensated instrument was coupled with the atomic absorption-flame emission unit to make it more accurate for analyzing metal-bearing solutions. A program to improve methods for determining individual rare-earth elements by X-ray spectrometry was begun in order to assist the uranium mines in their efforts to recover these values from waste mill streams. More rapid procedures were developed for analyzing smelter slags to provide data for monitoring electric-furnace operations. Research to update on-stream analysis of xanthate residuals in cyanide flotation pulps was continued so that variations in liquor concentrations with reagent pick-up by the mineral surfaces can be related precisely.

Mineralogical studies were carried out in connection with the research of the Division. One study was made to examine the response of various uranium-ore minerals to acid-leach attack, by means of mounting previously studied polished mineral specimens in a percolation column in which bacterially active acid-leach solutions were flowing. The progress of the acid attack was followed by means of ore microscopy. A wide range of leaching rates for the ore minerals present was observed, with uranothorite being readily leached in seven days while brannerite was still highly refractory in an exposure of more than 100 days.

METALS REDUCTION AND ENERGY CENTRE

The Metals Reduction and Energy Centre was created on October 1, 1969, for the following purposes:

a) To conduct studies of the energy requirements of the Canadian metals and minerals industries.

b) To assess the related transportation problems in supplying these energy needs and in developing markets for metallurgical fuels and their products.

c) To perform both research and development work up to the pilot scale:

- i) on the production of "further-processed" metal ores (particularly reduced iron ores) ferro-alloys, and other metal products;
- ii) on the application of energy to metallurgical processes, including fossil-fuel carbonization or conversion and metal-ore reduction; and
- iii) the abatement of air pollution arising from some metallurgical processes, especially those of the ferro-alloy industry.

d) To apply the results of these studies to obtain benefits for the Canadian economy through:

i) organization of co-operative formal government-industry groups, such as the Canadian Carbonization Research Association;

ii) organization of ad hoc technical committees, such as that formed to study special problems in the hydraulic transport of coals to be used for coking;

iii) consultation with industry, universities and government representatives; and

iv) the preparation of reports and papers not only to publish the results of research but also to identify opportunities and to offer solutions to problems associated with energy use in metallurgy and related industries.

Pyrometallurgical Pilot Plant

For several years a combination shaft-electric furnace (250 kVA) has been developed at the Mines Branch to obtain maximum productivity through the optimum use of various energy sources, including the hot reducing gases from the electric furnace and from gas burners. Extensive control data have been collected on magnetic tape through the "Datacom" link to the Control Systems Laboratory computer of the National Research Council. These data are now under analysis and a computer program for calculating the process-energy requirements is in preparation, first for the treatment of ilmenite ore, but also by generalization for processing iron-oxide pellets and other feed materials. This project is now being changed to investigate various factors of arc-furnace operation, such as slag composition, arc voltage and current, depth of slag, fume generation in the arc zone. The objective is to improve the economics of arc-furnace operation, to obtain better products and to minimize fume generation as a contribution to pollution abatement. For ferro-silicon furnaces, a study has been initiated on the pelletizing of furnace fumes to permit their recirculation. Increased emphasis will be placed on air-pollution aspects in the future.

Coking-Coal Program and Related Transportation Studies

Because of the present general shortage of good coking and combustion coals at prices acceptable to the large consumers, there is increasing world-wide interest in coals of western Canada. Hence, during recent months, testing in the Mines Branch technical-scale coke oven has been extended from coals for the Japanese markets to coals for South America, the United States and central Canada. A total of 132 tests, a new record, were made in the 500-pound pilot-scale movable-wall coke oven during the year, embracing studies of coal for the coal-exploration industry, coking-coal blends for the steel industry and research aimed at improving the coking process.

An extensive study has been initiated on the feasibility of transporting coking coals in water-slurry pipelines. New water-removal methods are under investigation in the Western Regional Laboratory (Edmonton — located in premises generously made available by the Research Council of Alberta) and the carbonization aspects of this project are under study at the new Coal Laboratory on the western outskirts of Ottawa, where a new 18-inch 800-pound-capacity movable-wall coke oven is now in operation, in addition to the 30-pound coke oven used for small-scale preliminary tests, and the 12-inch, 500-pound movable-wall coke oven which will soon be reconstructed. By year-end a solution to the problem of extracting coal from the water-slurry had been devised and a pilot plant was under construction. These testing facilities, operated with the co-operation of the Canadian Carbonization Research Association, grouping major steel and coking-coal companies, have been used in 1969-70 for the joint research program co-ordinated by its Technical Committee.

The Western Regional Laboratory has pursued its contributions to the improvement of coal and minerals beneficiation, mainly by means of compound-water cyclones. These units, invented, developed and manufactured in Canada, are gaining acceptance because of their efficiency and low cost. Also, special dewatering processes were developed during the past year to overcome the need for thermal methods of drying at coal-washery plants. A special design incorporating these new features was developed to control sulphur in Cape Breton coals and is now being considered by the Cape Breton Development Corporation.

To note other activities briefly, petrographic techniques have been evaluated for their usefulness in understanding western Canadian coking coals and are now used on a routine basis. In an effort to improve the transportability of coke, tests have indicated that coal,

crushed to coke-oven-feed size, may be used to fill the voids between the pieces of coke and later separated by screening at destination, and that oil can be absorbed into coke up to about 25 per cent of its weight. For coke-oven stamp-charging tests, a device for ram charging has been built for the 12-inch movable-wall coke oven which will allow oven tests at rigidly controlled bulk densities. Form-coking studies on a laboratory scale have been continued on five coals in bench-scale apparatus, and a prototype "spouting-bed" apparatus has been tested, as a preliminary step before considering the design of a "spouting-bed" furnace at the pilot scale. The oxygen-flask sulphur-analysis method has been improved for control use in coal or coke research and development work by using Arsenazo (III) as indicator. A new method has been developed for the removal of magnesium from artificial rutile. It is now being examined for patentability.

Energy studies on the economics of production, transportation, storage and utilization of Canadian coals have been continued, particularly as it now appears that the low-sulphur coals of western Canada may be needed for thermal power generation in Ontario as well as for coking, due to the rising demand for energy and the increasing need for air-pollution restrictions with the consequent need of coals of less than 1 per cent sulphur content.

MINERAL PROCESSING DIVISION

The Mineral Processing Division carried out basic and applied research in aid of the mining, ceramics and construction-materials industries and continued to supply expert advice to industry and other government departments.

Research to improve basic processes for concentrators of metal ores in the mining industry included development of new types of filter media, systematic study of cyclone operating parameters, and correlation of new methods of measuring ion concentration with the flotation behaviour of sulphides and oxides. The fundamental studies of the jigging process have resulted in development of a much simpler and more efficient method for concentration of ilmenite. Full-scale tests will be carried out by industry. Research to find a selective flotation process to separate talc from molybdenite in high-talc ores has continued with investigation of new talc depressants, the column flotation process and spherical agglomeration.

Applied research provided assistance to the mining and metallurgy industries in developing new mines, improvement in existing plants, and better utilization of resources. Preliminary investigations to provide metallurgical knowledge to industry on concentration of ore from new discoveries were conducted on 21 bulk samples covering the range of metals from gold to iron. Many of these were complex, e.g. silver-gold-lead-zinc-antimony; silver-lead-zinc-tungsten; and one of seven recoverable metals. Pilot-plant studies were made on several ores to confirm the feasibility of recommendations. Geographically, the sample origins ranged from Sable Island to Vancouver Island.

Assistance to the metallurgical industry included development of a process to recover and re-use chromite sands in a foundry operation. This process is now in operation. Assistance was provided to a Canadian producer in the development of a new method to process iron powder for use in powder metallurgy, and research continued on new methods of purifying iron mineral concentrates for preparation of iron powders.

Assistance was given to the ISO Committee on standardization of iron-ore testing procedures by conducting a statistical study of proposed screening methods.

Research in the industrial minerals field was directed to the solution of technological problems, conversion of waste materials, provision of technical advice and information. Activities in this field comprised projects for improved processing of Canadian industrial minerals, ceramics research, construction materials research, non-metallic minerals research and studies on the beneficiation and utilization of waste materials. Evaluations were carried out on a large number of industrial mineral samples supplied by industry, the public and other Government departments.

A long-range study of the floatability of non-metallic minerals has generated world-wide interest through departmental publications and scientific papers. Two patent applications, one on a biodegradable reagent for floating barite and celestite and the other for floating spodumene, were filed. Photometric sorting systems were devised for the concentration of uranium, limestone and lepidolite. New processes for spodumene, fluorite and celestite, and fluorite and barite, resulting from research in the Mines Branch, were transferred to pilot-plant recovery to determine their economic viability.

Evaluation of Canadian non-metallic minerals continued with work being carried out on sylvite-halite separations, gem stones from Baffin Island, rocks used for Eskimo carvings, marl, ultra-basic rocks, building stones from sandstone and white dolomite, scheelite, salt, barite, kyanite, clay, talc, magnesite, silica and lightweight aggregate raw materials. In a joint project with the Quebec Asbestos Mining Association, which carried out fibre-length and -distribution counts using the system developed at the Mines Branch, a statistical program was written from these results with assistance from the EMR Computer Science Centre. The magnetic susceptibility of chrysotile asbestos fibre was studied with the assistance of scientists from the Geological Survey of Canada.

Laboratory studies on by-product synthetic gypsum from plants in Alberta, Ontario and Quebec showed that a satisfactory gypsum wallboard could be processed from fertilizer plant residue. It was found that waste iron-oxide-precipitator dust from a steel plant could be used advantageously as a component in such clay products as facing brick and drain tile. Plans were made for establishing an inventory of mineral wastes in Canada so that priorities could be established on carrying out useful research on these materials.

The Construction Materials Section continued to lead the way in Canada in the establishment of rapid and accurate tests and standard methods for evaluating strength and durability properties of concrete and its ingredients. In co-operation with the University of Ottawa, a building supply company and a firm of consulting engineers from Ottawa, the Section studied means to determine potential strength of concrete in structures using the maturity concept and non-destructive methods. Data from a construction site in Ottawa were collected and analyses of the results are under way. Research in the development and modification of an accelerated test method for controlling the quality of cement during the production stage has been completed.

Research on the preparation, characterization and conversion of raw materials to ceramic products continued on such materials as alumina, zirconia, magnesite, clay and shale, kyanite and talc. Of particular interest was a study of a magnesite-talc deposit in Ontario which revealed that the ore was a potential source of 92 per cent refractory-grade magnesia and a high-quality talc. A long-term study of particle size and morphology of Canadian alumina continued with the aim of developing a material suitable for a substrate in the electronic industry. An improved method of measuring thermal diffusivity of ceramic materials, rock and minerals resulted from intensive laboratory research.

TECHNICAL SERVICES

The Technical Services Division has continued to provide engineering support to the various research centres and divisions in the Mines Branch. This support has been in the fields of mechanical engineering, electrical engineering and industrial instrumentation in order to provide the scientists and research workers with the type and quality of equipment that is necessary in their respective fields of research.

During the past year a considerable amount of both the mechanical and electrical effort of this Division has gone into designing and installing equipment at the Corkstown Road site. Existing equipment and apparatus moved from the Booth Street site, as well as newly acquired equipment had to be connected to the service facilities within the various buildings.

One of the major undertakings this year which called for close liaison between our electrical and mechanical sections as well as co-operation between our design staff and the research staff was the installation of the 18-inch coking oven which has a movable wall and can take an 800-pound charge. The oven was built by an outside contractor to drawings supplied by Bethlehem Steel Co., but a considerable number of instruments, such as temperature controllers and pressure recorders at various locations, had to be installed. As the natural working environment of a coking plant is normally very dirty, it was necessary to build a special room where all the control instrumentation could be installed. In addition to the oven proper a wide range of ancillary equipment such as levellers and pushers had to be designed and built so that the oven could be operated efficiently and in line with current industrial practice.

Another piece of equipment designed and built by the Division was a pulsating air-jig which was based on a small "bread-board" model used for feasibility studies. The enlarged version was designed to provide a variable number of pulses of air per minute as well as independent control over the volume of air required. This type of air-operated separator is of interest where

minerals require dry processing or where water is in short supply so that wet processing becomes impossible.

In conjunction with one of the research centres of the Branch, equipment is being designed and built for calibrating a coking oven while it is at operating temperature.

An experimental laboratory apparatus for measuring the magnetic susceptibility of small mineral specimens was developed and built for one of the research divisions. The apparatus allows small specimens of materials to be accurately located in a magnetic field which could be rotated around the specimen's vertical axis.

Apart from supplying the research divisions of the Branch with scientific apparatus and equipment, research and testing of mining drill rods and machinability studies were carried out for private companies. A major steel company requested the use of a specially designed lathe for machinability studies together with the services of our personnel.

Extended physical tests of mining drill rods to improve their fatigue life were undertaken for some private companies. Various types of steels were tested under both wet and dry conditions and the test specimens were subjected to different types of surface treatments that would impart compressive stresses to the specimen surfaces.

LIBRARY

The Mines Branch Library consists of the main library with a staff of three professional librarians and five clerks. There is a branch library in the Physical Metallurgy Division with a library clerk in charge, an active collection at the Mining Research Laboratories, Elliot Lake, with a clerk in charge, a collection at the Western Regional Laboratory in Edmonton with a technician in charge, and a collection at the Western Regional Office, Mining Research Centre, in Calgary with a technician in charge.

The library collection consists of 79,000 books and bound journals, and 12,000 documents and reports. Subscriptions to more than 900 journals are supplemented by publications acquired through exchange agreements with scientific and technical societies in all parts of the world. There are approximately 8,000 loans and photocopies provided each month on circulation, to both Mines Branch personnel and other libraries.

The Library's serials are publicized by means of the National Science Library's Union List of Scientific Serials in Canadian Libraries, and its books in the Union Catalogue of the National Library. In addition, our holdings are now announced in the Comprehensive List of Periodicals for Chemistry and Chemical Engineering by Chemical Abstracts Service, Columbus, Ohio.

There is no doubt that as time goes on more and more library tasks will be adapted for performance on computers. As a result, some of the Library's manual operations are now being redesigned so that data can be readily converted to machine-readable form when necessary.

OBSERVATORIES BRANCH

For approximately 70 years the Observatories Branch has been involved in two major disciplines, Astronomy and Geophysics. The astronomical work, originally involving only the astronomy of position, was begun for the measurement of time and to assist in the establishment of a geodetic survey. This work soon expanded to the study of the physics of stars and, as a corollary, the physical study of the only planet then available for direct observation — Earth. Astrophysical studies led to the establishment of the Dominion Astrophysical Observatory at Victoria in 1918, and of the Dominion Radio Astrophysical Observatory at Penticton in 1960. The geophysical work expanded into three separate Divisions — Gravity, Geomagnetism and Seismology.

On April 1, 1970 the Observatories Branch was dissolved with the transfer of astronomy to the National Research Council. The three geophysical divisions have been reorganized under the name Earth Physics Branch. One aspect of astronomy, positional astronomy, the original section for which the Observatory was founded,

remains behind. Physical methods of measuring time have become so accurate that we now know that the earth is a most imperfect clock; the vagaries of its rotation are related to conditions within the earth and it has now become a problem of geophysics.

ASTRONOMY DIVISION — OTTAWA

The Time Service, involving the time laboratory and the CHU transmitters, continued in operation throughout the year. Correct time is distributed to a number of users: Bell Canada, the R.C.M.P., the C.B.C. and a number of government laboratories. This service transferred to the Physics Division of the N.R.C. where it was combined with the Frequency Section with no interruption of service.

For many years the Division had attempted to perfect a Mirror Transit Telescope, a positional astronomy instrument of unique design. It was finally established that the instrument could not be made to meet the required degree of accuracy without transfer to a more remote site and extensive redesign. It was reluctantly decided to abandon the project; abandonment had been completed at the end of the fiscal year.

The remaining instruments of the positional astronomy groups, Photographic Zenith Telescopes at Ottawa and Priddis (near Calgary) and an experimental PZT at Ottawa have continued in operation throughout the year and, as mentioned above, will remain in the Earth Physics Branch.

Work in solar physics has continued. Observations with the solar magnetograph attached to the 80-foot horizontal telescope at the Dominion Observatory clearly indicated that the system was seriously hampered by poor seeing conditions at that site. Modifications were performed on the system to allow signal averaging methods to be used for overcoming the errors produced by rapid, random motions of the solar image. While the Solar Physics Section has transferred to N.R.C., this one telescope, with its associated laboratories, will be retained by the Section until current research projects are completed.

The major effort of the Solar Physics Section has been in the development of an optical solar patrol telescope (photo-heliograph) to be sited at Shirley Bay. The basic mechanical framework, constructed by Canadian Westinghouse Ltd., was delivered in September 1969. The completed telescope will provide high-resolution photographic records of solar active regions at time-lapse intervals as short as 0.1 second. Several optical systems for observing different portions of the solar atmosphere can be mounted at one time on an equatorially-mounted platform called a "spar". Mechanical construction was completed for the first of these systems — a photoelectric guider telescope for tracking the spar precisely on the centre of the sun. A digital data-acquisition and -control system was specified and ordered for monitoring and controlling the status of various environmental sensors and cameras on the telescope, and for recording the data on magnetic tape. The building for housing the telescope was substantially completed by the end of March 1970. Site testing adjacent to the building site continued through the summer of 1969 and provided further evidence of excellent seeing on favourable days.

METEOR PHYSICS

The Meteorite Observation and Recovery Project (MORP) progressed according to schedule during the year. Nine camera stations were constructed, completing the network of 12 stations covering the Canadian prairies. Cameras and electronic controls for all remaining stations were purchased for installation. One station was put into routine operation during the year, as a test station, and its performance fulfilled expectations by photographing a number of bright meteors. A computer program was written for the MORP program, which will take measures of meteor photographs and calculate the solar-system orbit and trace the dark flight trajectory to the ground.

The Meanook-Newbrook observatories continued their program of meteor spectroscopy until the end of 1969 when the equipment was prepared for moving to new sites near Ottawa.

DOMINION ASTROPHYSICAL OBSERVATORY — VICTORIA

On the occasion of the transfer of the D.A.O. to N.R.C. it is worth noting that since 1918 the Observatory has developed from a single telescope and a staff of seven to three research telescopes plus responsibility for work on Mount Kobau and a staff of 42 associated with the astrophysical division. The efficiency of the telescopes and their instrumentation continues to be improved with the result that for the coude spectograph of the 48-inch telescope with its dispersion of 2.4 A mm^{-1},

spectra are obtained in exposure times comparable with those required at the 200-inch Hale telescope. Accurate data reduction, which has always been a feature of the Observatory programs, has also been improved and digital and computer analysis methods are being worked out.

The 72-inch telescope was used for 1,148 hours on 193 nights during the year. The 48-inch telescope was used for 1,209 hours on 213 nights. This has been a good average year for observing, considering that the telescopes were out of operation for four nights for repairs, but it has been found that the average number of observing hours in recent years has been less than in the first years of the Observatory's operation.

A new optical shop was built under the supervision of the Department of Public Works from designs prepared at the Observatory and put into operation in January. The optical equipment bought for the Queen Elizabeth II telescope, with the exception of the large grinding machine stored at the University of British Columbia, is now in place. The principal task of the new shop will be the figuring of a new very-low-expansion 73-inch CER-VIT mirror blank to replace the 60-year-old plate-glass mirror of the main telescope. Great interest has been taken in the new shop by astronomical groups in Canada and throughout the world and many requests have been received to undertake precision optical finishing work for other observatories.

Twenty scientific papers were published by staff members during the year on topics such as the structure of the galaxy, binary stars, galactic clusters and loss of mass by hot supergiant stars, and the Observatory was represented at several international scientific meetings. Staff members have been invited to act as consultants on large-telescope and instrumental problems by the U.S.A., France, Germany, Italy, the United Kingdom and Australia. For example, Dr. E. H. Richardson spent five months in Texas at the 108-inch telescope in charge of the optics in a successful attempt to reflect a laser beam from the corner-cube reflectors placed on the moon by Neil Armstrong in July 1969; the moon's distance from the earth is now known to within a few inches.

Considerable improvements in the efficiency of the 72-inch and 48-inch telescopes were made during the year. New image slicers for the infrared and ultraviolet have been installed in the 48-inch and work has begun on an improved mirror-support system for the new 72-inch mirror. The process of automating the methods of measuring and processing the data obtained by the telescopes has proceeded rapidly and has contributed to a greatly increased output of scientific work. For instance, the 16-inch telescope on Mount Kobau was used very successfully with the Vidar Data Acquisition System to make over 3,600 observations of standard stars, members, clusters and associations, peculiar and reddened stars, etc.

The need for larger telescopes for the use of Canadian astronomers is very pressing and decisions are awaited from the Government in the very important question as to whether Canada participates in the 200-inch telescope to be built in Chile. The Science Council recommended this course in a report submitted to the Cabinet in September with the proviso that the 200-inch mirror be figured in Canada and that Canadians be responsible for 50 per cent of the work on the rest of the project. The design and optical teams drawn together to build the Queen Elizabeth II telescope are still available to work on any large telescope approved by the Government.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY

The Observatory is concerned with studies of a wide range of astronomical bodies, mainly through investigations of their radio emissions. It operates three major instruments: a conventional 25-metre paraboloid used at frequencies from 110-2,000 MHz, and two large arrays operating at 10 MHz and 22 MHz. A new supersynthesis telescope, now under construction, will be used for both continuum and spectroscopic studies in the 1-2 GHz range.

The main research projects of the Observatory have been concerned with studies of the low-frequency emission from radio sources and the galaxy, the distribution and motion of galactic neutral hydrogen, the structure and temperature of galactic ionized hydrogen, the angular structure of quasars, and the intensity variations of pulsars.

The observations with the 10-MHz array have been terminated and the catalogue of 124 sources published. The three observers who have used the array have been collaborating in the production of a map of the con-

tinuum emission for much of the northern sky. This will be used mainly for studies of the distribution of the diffuse ionized hydrogen regions in the galaxy.

The 22-MHz survey of the sky visible from Penticton has been completed and the observations terminated. A list of flux densities for 200 radio sources has been published, and a complete analysis should yield another 400. The 10 MHz and 22 MHz observations have been compared with higher-frequency observations in a detailed study of the low-frequency radio spectra. Preliminary computer reduction of most of the sky survey observations has been completed. This project will produce a complete map of the northern sky which will be used for studies of the spectra and volume emissivity of the non-thermal continuum emission and of the nature and distribution of galactic ionized hydrogen.

The Observatory has continued as a member of the Canadian Long Baseline Interferometer Group. Observations during the year were made on quasars using the Algonquin Radio Observatory (46-metre paraboloid) and the Arecibo 1,000-foot bowl, and on pulsars using the Penticton-ARO baseline. A paper on source structure using most of the early observations was published this year.

Observations on the time variations of pulsar intensity continued. This work included simultaneous observations at the DRAO and the Nuffield Radio Astronomy Observatory at Jodrell Bank. Correlation studies of this type can yield information on motions in the interstellar medium. A program has been developed which is capable of on-line analysis for all pulsar periods using the PDP-9 computer at the DRAO. It has been used mainly for a survey for new pulsars at high declinations using the 25-metre paraboloid at a frequency of 400 MHz. An extensive effort to detect several pulsars with the 22-MHz array produced upper limits to their intensities at this frequency.

The 100-channel spectrometer was used for a number of hydrogen-line studies, principally by observers from the University of British Columbia.

The cosmic-ray facility of the University of Calgary has been expanded. Their new 22-MHz array and directional shower array were completed and made operational.

GRAVITY DIVISION

The primary responsibility of the Division is to produce a complete gravity map of Canada and to provide interpretation of the maps where this might be of scientific or commercial interest. The Bouguer Gravity Map of Canada, published in 1968, has many areas still incompletely surveyed. A major effort has thus been made in field surveys.

a) A party supported by two helicopters and one fixed-wing aircraft established 4,500 stations in the area between Great Slave Lake and the Mackenzie Delta. Anomalies of interest include a remarkable circular high of 120 mgal south of Darnley Bay.

b) Approximately 900 stations were observed on sea ice in the Beaufort Sea in conjunction with hydrographic surveys of the Polar Continental Shelf Project. The area covered extends north from Tuktoyaktuk to latitude 73°30′N and between longitudes 130°W and 135°W.

c) During 1969, 400 underwater gravity stations were added to previous surveys in Lake Ontario, Lake Erie and Lake Huron.

d) One and one-half crew months were spent linking together various previous bench-mark surveys in southern Ontario and western Quebec.

e) Preliminary airborne gravity tests using highly accurate electronic navigational equipment were carried out in the spring of 1970 in the vicinity of Alexandria, Ontario.

f) A Differential Omega Navigational System was evaluated in the Mackenzie Delta for positional accuracy, strength, stability and feasibility for helicopter in-flight use for the Polar Continental Shelf Project.

g) The detailed study of the gravity field of the Sudbury area was continued in 1969. A total of 652 new gravity stations were recorded, including 62 in and around Lake Wanapitei which was surveyed in March. The remaining regional and detailed stations were observed in the summer with the use of air, road and rail transportation. Altogether 2,300 gravity measurements are now available in this region.

It is important that gravity observations throughout Canada, and indeed throughout the world, be reduced to the same datum. The final adjustment of the National Gravity Net is now under way. During the past year

several field crews carried out direct connections between National Net stations throughout Canada to supplement earlier gravimeter work. The Canadian pendulum apparatus has now occupied sites in Ottawa, Winnipeg, Edmonton, Vancouver, Yellowknife, Resolute and Fairbanks. These measurements will provide scale control for the National Net adujstments. For operational reasons, the number of primary stations in the National Net has been reduced to 58. It is expected that the final adjustment will yield a uniform set of observed gravity values for the primaries and some 200 associated ex-centres.

Intercontinental and gravity ties and measurements on the world calibration lines carried out by Canadian observers since 1963 for the First Order World Gravity Net (FOWGN) have now been submitted to Professor Morelli of the Osservatorio Geofisico in Trieste and chairman of Special Study Group No. 6 of the International Association of Geodesy, who, for the past year, has directed the assembly of data from all participating countries into a homogeneous unit. Upon completion of this task each participating agency will receive a copy of the assembled data for analysis and adjustment.

Parallelling the collection and reduction of data is the interpretation of the anomalies shown by the finished maps. Major interpretations of gravity anomalies have been completed in several regions including the Province of Quebec; Queen Elizabeth Islands; Alexandria area, Ontario; Straits of Georgia and Juan de Fuca, British Columbia; Bancroft, Ontario; northwest Ontario; and in the Interior Plains of Canada. Theoretical studies of crustal loading in Canada and in Hawaii were completed during the year and investigations of new mathematical methods for interpretation continued during 1969.

Two programs of major research interest made progress during the year. Multidisciplinary geodetic and oceanographic studies in the vicinity of the North Pole, begun in 1967, and sponsored jointly by the Observatories Branch and the Polar Continental Shelf Project, were continued in the spring of 1969. Scientists from the Federal Government, from private industry and from universities were flown to a camp within 30 km of the North Pole. From April 8 to May 4 the party drifted some 60 km with the pack ice. Gravity observations in the vicinity of the North Pole and gravity traverses from the Lincoln Sea to the North Pole and across the Lomonosov Ridge were made. Both Omega radio navigation in differential mode and sunshots using a much improved atmospheric model for refraction corrections were used for positioning. Other studies included continuous wind-velocity measurements, ocean-current-velocity measurements ranging in depth from 0.5 m to 200 m, and the establishment of a number of salinity-temperature profiles to a depth of 500 m. A 120-m-long hydrostatic level was developed to measure the tilt of the fluid level of the ice-covered ocean. On May 1, 1969, a downward tilt of 4.3 microradians in the direction 198° of Greenwich was measured.

A second research project which concerns the loading and attraction effects of the ocean tide has been carried on co-operatively with the University of Durham in England during the past two years. A method has been developed for determining the theoretical regional and global effects of the ocean tide from worldwide co-tidal charts, assuming a Gutenberg-model earth. Theoretical effects have been determined for Britain and western Europe and are presently being determined for the Canadian east coast and for Ottawa. Also with the cooperation of Durham University, a new watertube tiltmeter has been developed and a prototype has been operating for several weeks in a mine near Durham. A second prototype is now under construction and, when finished, will be installed near Ottawa.

It is very important that reduced gravity data be readily available for regional studies, either by Observatory scientists or by university or commercial geologists. An IBM 360/65 disc retrieval system was installed some time ago and operated satisfactorily over the past year. It has been used extensively by the petroleum industry particularly those companies working in the Canadian Arctic. Several new features have been added.

Studies of proven or suspected meteorite craters have continued. They have been mainly concerned with sampling and laboratory investigations of material from the craters at Lake Mistastin, Labrador, Charlevoix, Quebec, and Brent, Ontario, for further analysis of shock metamorphism and crater structure.

GEOMAGNETISM DIVISION

The information on the direction and intensity of the earth's magnetic field shown on the magnetic charts of Canada, aeronautical and marine navigation charts, and

topographical maps, comes primarily from high-level airborne surveys carried out by the Division of Geomagnetism. The surveys are made in alternate years, because of the lower unit costs of a large-scale operation. No airborne survey was made in fiscal year 1969-70, but data from the early 1969 survey of British Columbia and the northeast Pacific Ocean was analyzed and prepared for publication. Several large-scale magnetic anomalies were discovered, most notably one parallel to the coast east of Vancouver Island, and a system of deep-seated anomalies 250 miles long and 120 miles broad in the Fort Nelson district of northeastern British Columbia. The explanation of these features will have important consequences to the understanding of the geological history and hence the distribution of the mineral deposits of western Canada.

Magnetic charts must be revised every five years because the geomagnetic field is constantly changing. To bring the data from earlier surveys up to date, measurements are made on the ground every few years at each of 100 carefully marked repeat stations, uniformly distributed over the country. During 1969, 26 such stations were occupied, in Newfoundland, Saskatchewan, Alberta, British Columbia and the Northwest Territories.

Variations in the direction and intensity of the geomagnetic field were recorded continuously at magnetic observatories in the following locations: Alert, Resolute, Baker Lake, and Mould Bay, all in the Northwest Territories; St. John's, Newfoundland; Poste de la Baleine, Quebec; Ottawa, Ontario; Churchill, Manitoba; Meanook, Alberta; and Victoria, British Columbia. In addition to the permanent observatories, unattended magnetic recording stations were operated in Manitoba at Lynn Lake, Thompson, The Pas, and Winnipeg, in a co-operative research project with the United States National Aeronautical and Space Administration involving the synchronous satellite ATS-5. Special magnetic recordings were made at four stations in the Atlantic Provinces during the solar eclipse of March 7, 1970, to study the magnetic variations due to the sudden decrease in the electrical conductivity of the ionosphere as the moon's shadow swept across it.

An investigation of the electrical conductivity and structure of the crust and upper mantle beneath Ellesmere Island was extended with the simultaneous recording of magnetic variations for five weeks at Meighen Island, Alert, and Cape Morris Jesup on the northern tip of Greenland. Twelve recording stations were occupied on a line between Prince Rupert, British Columbia, and Hinton, Alberta, in a similar study of deep crustal structure.

The Paleomagnetic Section completed a study of the magnetic properties of rocks dredged from the Mid-Atlantic Ridge, and proposed an explanation of the intense magnetic anomalies observed over the centre of the Ridge. Further information on the relative motions and rotations of continents was obtained in an investigation of Permian and Triassic rocks from the Dinaric Alps. Progress was made in deriving a magnetic chronology of the Paleozoic and late Precambrian.

SEISMOLOGY DIVISION

The standard network of seismic observatories equipped with short- and long-period seismographs continued as in the past, except for the enforced closure of the station at Coppermine, N.W.T. This followed the transfer of the meteorological ionosonde program at that site to elsewhere in the Arctic. The program of continuous instrumental updating and calibration continued on schedule, with a major field project at each of four high Arctic observatories. At one of these observatories, Alert on Ellesmere Island, additional specialized narrow-band, high-gain long- and short-period seismographs were introduced as part of a network evaluation leading to the better identification of underground nuclear explosions. Some improvements were initiated to make more Canadian abstracted seismograph data available for immediate epicentral determination by international agencies.

The local seismograph stations for more detailed study of Canadian seismicity continued unchanged, as did the extensive strong-motion network in western Canada: field parties routinely maintained and checked the latter network.

During the year, the new seismic zoning map for Canada described in earlier annual reports was officially accepted for the 1970 Revision of the National Building Code: the changes introduced in building and insurance practices resulted in an increase in the number of technical seismicity requests to the Division. A policy was adopted of making a small charge to recover direct additional computer usage costs, for cases where this was necessary to handle the requests.

The usual number of minor shocks were reported in both eastern and western Canada: one earthquake in the Laurentians in October was widely felt from Montreal to Ottawa and resulted in many public enquiries and expressions of concern and surprise. It is clear that despite every effort, the earthquake risk in Canada is poorly appreciated and understood by the general public. In order to help remedy this situation, a public relations leaflet describing this risk and some relevant work of the Division was drafted during the year.

Micro-earthquake field studies were undertaken to investigate further the extensive active earthquake sources discovered the previous year in the Coast Ranges near the northern British Columbia-Alaska border. This work is now being analyzed and prepared for publication as part of a continuing study to understand the tectonic fabric of western Canada, why earthquakes occur and why they occur in certain spatial patterns which are still only partially unravelled.

The techniques for the routine determination of the parameters of all significant Canadian earthquakes and their publication in an annul series were modified in an effort to make this important service available on a more current basis. However, the series, with our best efforts with the available manpower, remains about five years in arrears.

The first stage of a modernization of the short-period seismic array at Yellowknife was completed with an encouraging and positive assessment of the feasibility of radio telemetering and on-site computer control. Planning for the conversion is complete, and over a three-year period the medium aperture array will be completely converted to a radio telemetered system with computer control of the operating parameters, state of serviceability, etc. In addition, during the year under review, vault work was completed for installation of a third long-period element, when laboratory construction is complete: this will provide a minimum tripartite long-period array at Yellowknife with data available in a form suitable for digital machine processing. The analogue and digital data-processing laboratory in Ottawa was updated with the addition of oscilloscope read-out.

Considerable progress was made in research into the problem of the detection and identification of underground nuclear explosions: notable was the completion of experimental work on a study of the regional variability in the detection capability of the short-period array, further studies on identification at low yields using surface waves with emphasis on the data recorded in a format suitable for machine processing, and the development of an in-house system for determining the approximate epicentres of events anywhere in the world within one to two days, using abstracted data reported routinely to Ottawa from the Canadian network.

Research continued, with a number of publications, into the mechanism of earthquakes, the lateral variation in upper-mantle properties derived from surface-wave-dispersion studies, the structure of the deep interior of the earth and the derivation and understanding of the theoretical seismograms from nuclear explosions.

In July, the crustal group conducted a wide-angle reflection-refraction survey along a 100-km line near Yellowknife, N.W.T. The experiment was designed to test the effectiveness of a new technique in a structurally simple area, and to design ways of handling, processing and interpreting with digital means the nearly 1,000 seismograms of shots obtained with such techniques. In August, 20 large explosions were detonated using surplus naval ordnance in a lake in British Columbia. The project, code-named Edzoe, provided a repetitive source to 11 Canadian and U.S. university and government groups operating throughout western Canada to study the composition of the crust and upper mantle. Reduction of data obtained in earlier field projects continued and some theoretical studies were published.

The geothermal-studies group continued field measurements at widely scattered locations throughout Canada made available by commercial companies. In addition, further measurements were made in unusual Arctic lakes and some fiords. As a service to the oil-exploration industry, some deep-permafrost information was published, and plans were made to increase the number of measurements in permafrost regions. An interesting and unusual study in paleoclimatology was completed using heat-flow measurements made in northern Ontario, and an analysis of certain laboratory techniques completed and sent to press.

The level of visitors, contributions and papers sent to press and papers given at national and international meetings remained steady. The Division assisted the Committee of the Conference on Disarmament in Geneva on Comprehensive Test Ban Problems.

POLAR CONTINENTAL SHELF PROJECT

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Arctic coast of Canada, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Archipelago and the waters between them, and other areas that may be of special interest. The Project serves in part to facilitate Arctic researches and surveys of other units of the Department of Energy, Mines and Resources; in part it carries out, with its own personnel, work that is unique within the Department; it also serves as the vehicle through which the investigations of other government agencies are carried out in the Arctic Archipelago and the Arctic Ocean; and it provides facilities and support for approved university researches in the area.

The Project's field survey will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean that are of interest to Canada and which can be reached with available logistics, and those parts of the archipelago and the mainland not studied by other agencies of the Department.

Field activities in 1969 were carried out from January to October. Studies continued till December and ranged from the lower Mackenzie River valley to the North Pole and northern Greenland. The main bases of operation were Tuktoyaktuk, Resolute and Alert.

In addition to the Department of Energy, Mines and Resources 22 other agencies were involved in or received assistance from the operations of the Polar Continental Shelf Project. Among them were 11 universities (four American and one Japanese), and Canadian government departments.

The 1970 program was to be, in the main, a continuation of that of 1969. The main emphasis was to be placed on the Beaufort Sea area.

The following is a summary of the work done in 1969, by major scientific field.

Climatology

Study was continued of the present behaviour of a small high Arctic icecap — the Meighen Island icecap — and its influence on and reaction to the local climate. Emphasis was laid on the energy exchange between the atmosphere and the earth's surface of known uniform physical properties.

Geology, Marine

In the Mackenzie River delta and inner Beaufort Sea, the study of the geology of the sediments, the processes of sedimentation, and the present and past organisms of the sea floor in an Arctic delta environment was continued.

Geology, Terrestrial

The study of the nature and distribution of permafrost in the Mackenzie River delta and the characteristics and mechanics of development of permafrost land forms was continued. Special attention was given to the development of pingoes and the occurrence of permafrost around lakes and the ocean shore. A shallow seismic survey of the thickness of permafrost and the structure of poorly consolidated sedimentary deposits of the Tuktoyaktuk peninsula was also undertaken. Another continuing study related to the recent geological history and the development of landforms in western and central Banks Island. To understand the stratigraphy of the economically promising area of the central Arctic Archipelago, a detailed study was carried out of the faunal variations in selected Paleozoic formations within the Franklinian geosyncline. Studies were also conducted in the stratigraphy and structure of the Mesozoic formation in the lower Mackenzie River valley. Mapping of vegetation types and study of peat deposits were carried out to determine the recent geological evolution of the western Arctic Islands.

Glaciology

The study of the mass balance and morphology of the thinnest and driest of North American Arctic glaciers — the Melville Island icecaps — was continued. Surveys were made of the accumulation, wastage and movement, and detailed aerial photography was carried out. Study was also continued of a small polar ice mass, the Meighen icecap. Experiments were made to determine the thermal and dynamic relationships of ice in a high Arctic environment. Further studies were carried out on the crystallography and internal structure of the ice mass to determine its history and climate during the recent geological past.

Geomagnetism

The project provided for measurements of the nature and variations of the earth's electromagnetic field along the edge of the Arctic Ocean basin on either side of a strong-conductivity anomaly. The anomaly was previously studied in the Alert-Robeson Channel area at the northeast edge of the Canadian Arctic Archipelago.

Gravity

Regional mapping of the gravity over the continental shelf and continental slope in the Beaufort Sea were carried out. The scale was 1:500,000. Mapping of the gravity over the lower Mackenzie River, valley and delta was completed. The scale was 1:250,000.

Heat Flow

Measurements were made of the flow of the geothermal heat from the earth's crust at selected Arctic locations.

Hydrography

A survey of the coastal area of Beaufort Sea was made for charting at a scale of 1:100,000. Continuous-profile soundings were made over parts of the submerged delta of the Mackenzie River, for evaluating potential sites for harbours for supertankers. Another survey was made over the continental shelf and continental slope between the Mackenzie River delta and Banks Island for charting at a scale of 1:500,000.

North Pole

A multi-discipline investigation — geodesy, gravity and oceanography — of a region near the North Pole and along the meridian 60° West was carried out.

Position Determination

Positions were determined of a number of selected points along the north coast of Greenland. As a result errors in the present maps were reduced. In the Beaufort Sea area evaluation was made of the signal strength and stability obtainable with the Omega navigation system in high latitudes and its accuracy compared with the Decca Lambda system.

Sea-Ice Studies

For the ninth successive year, a systematic aerial survey was carried out of the distribution, nature and movement of sea ice in the main channels of the Arctic Archipelago. Under the *Manhattan* project, the thickness, temperature profiles, salinity distribution and structure of the sea ice at selected locations were determined. These were along the route that the S. S. *Manhattan* proposed to take in late summer. A continuing study was under way of the stresses and strain relationships of the annual sea ice in Kugmallit Bay.

Miscellaneous

Support was also provided for 20 other studies, such as: a survey of the small mammals of the coastal Yukon and western Mackenzie district; biological and glaciological investigations in northern and eastern Devon islands; paleozoic paleontology and petrology in northern Banks Islands; geomorphological studies on Baffin Island; a continuing comprehensive biological and ethological investigation on Bathurst Island; archeological studies in the Mackenzie Delta region.

Mineral Development Sector

MINERAL RESOURCES BRANCH

The Mineral Resources Branch is responsible for resource-economic research, program development, and policy formulation in the field of non-renewable resources. The purpose is to contribute towards attainment of optimum economic and social benefits for the nation through effective mineral resource management in concert with Departmental objectives. The Branch continually seeks to identify and evaluate factors affecting mineral policy and mineral industry.

The Branch collaborates with other departments and agencies of government and with industry, and conducts research and field investigations into mineral problems, policies and programs on a commodity and industry basis, and in a regional, national and international context. The Branch continuously monitors trends, and integrates and analyzes data on a broad spectrum of mineral industry activities ranging from basic resources through exploration, development, processing, transportation, marketing and consumption. This information provides a basis for decision-making within the Department and within government on non-renewable resource policy, as well as the raw material for publications useful to those concerned with mineral economics.

The Branch is organized into three functional Divisions:

1) Research and Planning, 2) Minerals and Metals, and 3) Taxation and Legislation. Technical and administrative support groups are common to all Divisions. The Branch is changing towards a type of management organization that will facilitate interdisciplinary work.

Links with public agencies complement relationships with industries. Highlights that follow indicate the scope of Branch activities in the 1969-70 fiscal year.

Regional Development

Minerals administration practice in British Columbia was examined at the request of the British Columbia Department of Mines and Petroleum Resources. This co-operative study, begun late in 1968, was completed in the spring of 1970.

A federal-provincial program for mineral development in Manitoba was agreed upon and research initiated in the spring of 1970. The first phase consists in forecasting and evaluation of the economic mineral potential. The program will continue into 1972.

The Branch collaborated to an increasing extent with the Department of Regional Economic Expansion and with the provinces in furthering regional mineral development. Special studies pertaining to Newfoundland, New Brunswick and Quebec were undertaken in 1969-70.

Northern Development

A study, begun in 1968 and continuing in 1970, concerns the rail and road transportation needed for the development of northern British Columbia and the Yukon. The interdepartmental study, in collaboration with a private consulting firm, has meant a major involvement by the Branch in all phases of the project, with particular responsibility for assessing the economic mineral potential and how mineral development could contribute to development of the region. Methods developed with the consultant were successfully applied in full co-operation with private exploration managers. A report on the forecasting techniques used and the results obtained will be published in 1970.

The Branch continued to provide advice on mineral matters to the Department of Indian Affairs and Northern Development and to participate in interdepartmental activities concerned with northern economic development; one of these is road construction in the two territories.

Interdepartmental Commodity Committees

The Branch is represented on a number of interdepartmental commodity committees responsible for recommendations concerning mineral-commodity problems of industries, regions, or all of Canada. The data and research systems of the Branch contribute to decision-making as the need arises. Recent examples of governmental concern include: ensuring that an adequate supply of refined copper was available to the domestic fabricating industry during a period of world shortages and price disparities; and production-price problems of the Canadian potash industry.

Taxation

A study was begun of the implications for the mineral industry of the tax changes proposed in the White Paper on Tax Reform.

Analyses and recommendations were provided to the Department of National Revenue with respect to tax benefits under the Income Tax Act which are applicable to the mineral industry. Reports were prepared on 17 applications for three-year tax exemptions, and on two applications for the special oil-pipeline depreciation allowance.

Recommendations were made to the Department of Indian Affairs and Northern Development in the preparation of a proposed revised Yukon Minerals Act.

General Advisory and Consultative

As a result of continuing in-depth studies and analyses of all mineral commodities either produced in or of importance to Canada, the Branch provides information and advice on a broad scale to mineral-industry representatives and the general public through personal office interviews, correspondence, telephone and publications.

International Activities

The Branch represents the Department in intergovernmental organizations and international associations that embrace mineral-industry matters. Background studies are provided and recommendations on Canadian positions are made to Canadian government delegations on which Branch officers often serve.

The Branch represented the Department on the Canadian delegation to the International Lead and Zinc Study Group and attended the 13th Session in Geneva in October 1969. Contributions were made to the technical-economic studies and to the statistical needs of the study group. The Branch participated in matters concerning the Third International Tin Agreement, and towards the end of the year a Canadian team, including a Branch member, was prepared to commence negotiations for the Fourth International Tin Agreement to become effective on July 1, 1971, for a five-year period.

Mineral-industry data were supplied to OECD groups, including the Special Committee for Non-Ferrous Metals, and the European Nuclear Energy Agency. In conjunction with the latter group, of which Canada and the United States are members by virtue of their prominence in the nuclear-energy field, an officer of the Branch attended meetings and reviewed nuclear-energy facilities in a number of west European countries. A study of Canada's uranium production, reserves and short-term demand was presented to the meeting. The Branch also participated in meetings of the OECD Special Committee for Iron and Steel, the UNCTAD Special Committee on Tungsten, the UN ad hoc meeting on iron ore, and the UN's ECE Steel Committee. The Branch also co-ordinated a tour by the ECE Steel Committee of Canadian steel facilities, and worked with counterparts on a related tour of United States facilities.

The Branch has a continuing program of educational mineral filmstrips designed for use in high schools. The photographic library and mineral-resource records centre continued to be enlarged. The Branch contributed several sections on minerals to the Canada Yearbook, and prepared papers for presentation at international meetings and for publication in technical journals.

Foreign Aid

The Department, through the Branch co-ordinator, provided recommendations to the Canadian International Development Agency on 58 applications for technical training for foreign trainees. These programs were sponsored through the various regional plans of the Agency and through the United Nations. Practical training was arranged partly within the Department of Energy, Mines and Resources and also in private industry, provincial government departments, and university graduate schools. During the fiscal year ending March 31, 1970, 26 programs had been completed, and at the same date the arrival of 37 additional candidates was expected. Besides post-graduate training programs, five foreign undergraduates were assisted in finding summer employment, and 50 attended the Summer Survey School provided by the Department.

Through the foreign-aid services provided, four technical advisers to the Moroccan government were recruited in geochemistry, geophysics, petroleum geology and economic geology. Several observation tours of the Canadian mineral industry were arranged for foreign mineral specialists and metallurgists.

The Branch co-ordinated a mineral investigation in Niger for which a report was prepared to assist the Canadian International Development Agency with an evaluation of the phosphate resources of that country.

Consultation and advice on proposed bilateral capital assistance was provided to the Agency in respect to requests from the governments of Ethiopia, Guyana, Niger and Upper Volta. Comments were also prepared on several multilateral projects of the UNDP. The Branch provided the representation of the Department to the Interdepartmental Committee for Development Assistance within the UN.

Mineral Occurrence Index

The Branch maintains an index of Canadian mineral occurrences as part of its data base which is used in commodity studies and regional analysis. The data are also used by those interested in mining and mineral exploration in Canada. The index contains comprehensive summaries with provision for revision of location, geology, history of ownership, development, and results of development work, supplemented by map and literature references, on some 12,500 mineral occurrences. These summaries, each on individual cards, are arranged in conformity with areas of the National Topographic System.

Agreements for the exchange of mineral-occurrence information were in effect with the Nova Scotia Department of Mines, the Ontario Department of Mines, the British Columbia Department of Mines and Petroleum Resources, and with the Northern Economic Development Branch of the Department of Indian Affairs and Northern Development.

Priority was given during the year to indexing the mineral occurrences of Yukon and the Northwest Territories, and by the end of the review period about 80 per cent of the indexing for this area had been completed.

Roads to Resources

The Roads to Resources program was a national effort designed to provide access to areas potentially rich in natural resources. The administration of the agreements, which provided $7.5 million as the federal share of each province, was transferred to the Branch in October 1966.

Federal payments to March 31, 1970, at which time all payments under the program had been completed, amounted to a total for all provinces of $74,988,792.

The Emergency Gold Mining Assistance Act

The Act is administered in the Mineral Resources Branch under the direction of the Assistant Deputy Minister (Mineral Development).

Inspection engineers from the Branch conduct regular inspections of gold mines receiving assistance. They report upon all aspects of the mining operations which affect the assistance payable under the Act. In particular, they determine the proper classification of exploration and development expenditures, review the

allowance of costs which are in question and report on mining and milling practices and on the ore reserves of the mines.

The Audit Services Branch, Department of Supply and Services, examines interim applications for advance payments of assistance and carries out the final audit of the accounting records of each applicant.

The Act was passed originally in 1948 to extend the operating life of the gold mines and thereby to minimize economic and social hardships for the dependent communities due to mine closures.

By an amendment passed on November 28, 1967, the application of the Act was extended for three years to December 31, 1970.

The Minister of Energy, Mines and Resources, stated in the House of Commons on November 24, 1969, that an interdepartmental study group was examining the implications of the termination of the Act, and that a decision concerning renewal of the Act would be made after the report of the study group was received in the early summer of 1970.

An amendment to the Act in 1963 contained a restriction limiting eligibility for assistance in the case of lode gold mines commencing production after June 30, 1965, to those providing direct economic support to an existing mining community. A gold mine is deemed to provide such support if more than 50 per cent of the persons employed at the mine reside in the established mining communities listed in a schedule to the Act.

The number of lode gold mines receiving assistance under the Act has declined from 87 in 1948 to 33 in 1969, without, however, resulting in a decline of the total amount of money paid out annually in assistance. This is due to constantly rising costs of mining.

The amount of assistance payable to an operator depends on the amount by which the average cost of production exceeds $26.50 per ounce.

When calculated on the basis of all eligible ounces produced, the maximum assistance payable amounts to $10.27 per ounce.

The amounts paid to gold mine operators to March 31, 1970, for the years 1948 to 1969 inclusive totalled $275,152,190.84 on a production of 58,636,593.380 fine ounces of gold.

Figures for the calendar year 1969 were not yet complete at this writing, but the total was expected to come to between 14.5 and 15 million dollars.

Publications

The Branch published reports in the *Mineral Information Bulletin* series on iron ore, primary iron and steel, the economic character and change in the Canadian steel industry since 1945, mineral-resource development in the Atlantic Provinces, summary report on mineral-industry development in Manitoba to 1980, and also the regular preliminary annual review of the Canadian mineral industry. Also completed were four *Operators' Lists*, the 1967 *Canadian Minerals Yearbook,* and the nineteenth edition of the popular Map 900A *Principal Mineral Areas of Canada.* Work proceeded on world trade maps related to iron ore and potash and on reports concerning various other commodities, in a Canadian and international context.

EXPLOSIVES DIVISION

The high rate of fatal accidents in the explosives industry during the early 1900s emphasized the need for control over explosives, and the first Explosives Act was drafted and introduced into the House of Commons in 1911. The early recognition of the hazard and the willingness of the industry to accept controls have combined to make the explosives industry one of the safest in Canada.

The Explosives Act is primarily an act of public safety to control the manufacture, authorization, storage, sale, importation and transportation of explosives by road. Control is exercised by a system of licences and permits supported by inspections. All licences are issued from the Explosives Division office in Ottawa.

The volume of work at the head office increased notice-

ably during the year, partly due to acts of terrorism in the Province of Quebec. However, due to the streamlining of operations, the existing clerical staff was able to handle the increased work.

One of the prime responsibilities of the Explosives Division is concerned with the manufacture of explosives. The number of factories licensed under the Explosives Act continued to increase during the year and reached a total of 48 at the end of 1969. This increase was largely due to the continued expansion of explosives-manufacturing facilities at the place of use. A number of factories for the manufacture of slurry-type explosives, supported by bulk mix trucks and bulk pump trucks, have been located at many large open-pit mines. We expect this trend to continue in the future.

Members of the Division investigated several accidents during 1969. Although there were a number of quite serious accidents in the manufacture and transportation of explosives, none resulted in any fatalities.

In manufacture, four separate fires in smokeless powder presses at a plant at Valleyfield resulted in one serious injury. These incidents have led to a close study of the various aspects of this operation. There were four separate explosions while waste explosives were burned at various plants. There were no injuries, but these incidents resulted in a complete review of procedures for destroying waste explosives. Ten separate explosions during primer preparation at Valcartier resulted in five injuries. The frequency of these incidents causes concern, and has led to a review of these operations.

There were 11 accidents in the transportation of explosives, but none resulted in fire or explosion of the cargo. An engine fire of a bulk slurry truck was extinguished by the built-in fire extinguishing system required by the Division of these vehicles.

Members of the Explosives Division promote safety programs and regularly meet with members of the industry, federal and provincial government agencies and other groups involved with the handling of explosives. The Division also has available for distribution safety literature on the storage, handling and transportation of explosives.

A separate, more detailed report of the activities of the Explosives Division is published regularly.

Water Sector

MARINE SCIENCES BRANCH

The prime objective of the Marine Sciences Branch is to provide to public and private individuals and agencies of Canada technical information on those physical factors of the marine environment affecting the economy of Canada.

This requires the collection and interpretation of data describing the physical properties of the waters of the three oceans bordering on Canada. It requires, also, surveys of the geology and geophysics of the continental shelves over which Canada maintains jurisdiction and of the adjacent deeper portions of the Atlantic, Pacific and Arctic oceans.

The work of the Branch can be grouped into two main activities: hydrography and oceanography. In support of the two sciences the Branch operates a fleet of ships.

The Branch is organized along regional lines with offices in Dartmouth, Nova Scotia; in Victoria, British Columbia; and in Ottawa. The headquarters is situated in the Department of Energy, Mines and Resources complex in Ottawa.

During 1969-70 the Department's seagoing fleet travelled a total distance of 196,000 nautical miles. Changes in composition of the fleet included decommissioning of CSS *Acadia* on the East Coast after 56 years of service as a hydrographic vessel; and on the West Coast *Marabell,* a veteran of World War II, finished her long adventuresome career.

Another World War II vessel, *Radel* II, was acquired from the National Research Council and now is working on the Great Lakes; while MV *Martin Karlsen* and MV *Lac Erie* are serving on three-year charters.

CSS *Hudson* commenced her circumnavigation of the two Americas.

CSS *Parizeau* was converted from its role as a tidal survey vessel for temporary duties as a hydrographic vessel. Four 25-foot Bertram survey launches were acquired and fitted.

At the Canada Centre for Inland Waters three new craft were acquired, these being a 44-foot survey vessel of aluminum construction, a 34-foot steel launch, and a 40-foot pontoon craft.

HYDROGRAPHY

The Branch collects and publishes bathymetric data of Canada's navigable waters and of adjoining international waters essential to the safe, orderly and efficient conduct of commercial, recreational and defence shipping. This involves the preparation and publication of charts, pilots and tide and water-level almanacs.

The distribution of Canadian Hydrographic Service charts continued to increase at Ottawa and Victoria to an annual total of 318,400, representing a 3 per cent increase over the previous year.

The Service produced 279 new charts during the period. These comprised 34 standard navigation charts, 23 special charts, 12 charts in advance-print form, 76 new editions, 93 corrected reprints, 37 reprints and four supplementary prints.

Highlights among the new charts were :

a) Three offshore fisheries charts and a small-scale general chart of the Atlantic.

b) The first in a new series of metric charts of the entire Canadian Arctic.

c) The first in a projected series of small-scale bathymetric charts covering the continental shelf and the Great Lakes.

d) The prototype of a series of natural-resources charts at scale 1:250,000 showing bathymetric, magnetic and gravity information on the continental shelf.

e) Six charts showing Canada's territorial waters and fishing-zone limits, four on the Atlantic Coast and two on the Pacific Coast.

f) A chart of the surficial geology of the sea floor between Halifax and Sable Island. This chart was prepared in conjunction with the Geology Section of the Bedford Institute of Oceanography.

In August a new unit was established to investigate and develop the detailed charting of sea-floor topography and undertake physiographic studies with particular emphasis on the natural resource and bathymetric charting of the continental shelf.

The Sailing Directions section published a new edition of Volume 2 of the British Columbia Pilot and nine supplements to existing pilots.

Canada has continued to support the controversial charting of the deep parts of the world's oceans. The Canadian Hydrographic Service assumed responsibility for the maintenance of bathymetric plotting sheets in the western and eastern Arctic and along Labrador Coast which were formerly undertaken by the United States of America and the Federal Republic of Germany. A substantial amount of data on General Bathymetric Charts of the Oceans (GEBCO) was also exchanged with Great Britain, France and the Federal Republic of Germany during the year for inclusion in other plotting sheets for which these countries are responsible. The GEBCO Section also completed an extensive investigation and compilation of the nomenclature of the undersea features to be shown on new bathymetric charts of the Grand Banks of Newfoundland and Flemish Cap.

In addition to routine duties, the Nautical Geodesy Section provided a uniform control-data base for the St. Lawrence River surveys and the Ship Channel Division of the Department of Transport. The investigation and analysis of survey control in the Pacific Region was continued and the first phase, data conversion to computer cards and a check of the values, was completed.

Work continued on automating the cartographic processes of the Canadian Hydrographic Service. At the University of Saskatchewan research and development of the digitizer, general-purpose control computer and automatic drawing table are nearly complete. Most of the work during the past year concerned the analysis, design and development of the many control-computer programs and the testing of those programs through the basic system.

The Field Staff Training section conducted a six-week intermediate course at Ottawa for hydrographers from the three regions and a basic hydrography course was given to 13 new hydrographers. Participants in the basic course took their classroom training at Ottawa from October to the end of December and early in January sailed from Dartmouth, Nova Scotia, aboard CSS *Baffin* for a 2½-month training cruise in the Caribbean. For five weeks basic field training exercises were carried out in the Grenadines and the Bahamas. The results of these surveys will be sent to the British Admiralty for inclusion in its charts of the area.

The Service continued to provide guidance and advice on the technical problems in the formulation of a policy on national territorial waters.

The field surveys of the Canadian Hydrographic Service are managed through three regional offices situated in the Bedford Institute of Oceanography, at Dartmouth, Nova Scotia; in Ottawa; and in Victoria, British Columbia.

On the Atlantic Coast CSS *Baffin* completed the hydrographic and geophysical survey of the eastern part of

the Gulf of St. Lawrence and in October carried out a Lambda evaluation study to determine the accuracy of the Lambda system for the precise definition of undersea positions.

CSS *Kapuskasing* finished the survey of nearly the entire area between Funk and Fogo Islands off the northeast coast of Newfoundland; and CSS *Acadia* carried out two projects — a check survey of the critical area in the approaches to the Strait of Canso for deep-draft shipping and the survey of the sheltered but treacherous passage between the Fogo Islands and the mainland.

Revisory surveys along Nova Scotia's southwest coast, Passamaquoddy Bay and the Avon River to Hantsport were undertaken by CSS *Maxwell;* the headpond of the Mactaquac Dam on the Saint John River, the site of a new recreational area, was also surveyed.

Hydrographers also served aboard the CCGS *Sir John A. Macdonald* during her escort of the SS *Manhattan* through the Northwest Passage.

Projects designed to automate hydrographic surveys, improve navigational accuracy and assess accuracy standards were continued in 1969. Among these were the development of a digital echo sounder and the testing of satellite navigation equipment as well as the fitting out of a survey launch with data-logging equipment.

Field operations in inland waters continued to be essentially shore-based.

A party aboard the 37-foot survey launch *Verity* checked the charts between Kingston and Quebec City following a preliminary reconnaissance by helicopter.

Basic hydrographic surveying designed to meet the demands of recreational boating continued. The Lake of the Woods survey party worked the third year of a multi-year program and completed the central sections of this large island-studded lake. The Lake of Two Mountains survey began and the Rideau Lake system was surveyed between Kingston and Smiths Falls. Sounding control was established along the St. Lawrence River between Kingston and Brockville.

A Hydrodist-positioned examination was made of the navigation channel at Batiscan on the Lower St. Lawrence River and a survey to verify the positions and bearings of navigation ranges and to confirm the positions of the dredged or natural channels commenced at Montreal and progessed northeastward along the St. Lawrence Ship Channel.

To explore more efficient methods of collecting and processing field data a development-production survey of the Lower St. Lawrence River was initiated at Tadoussac. Sounding vehicles included eight launches, a sidewall air-cushion craft and auxiliary vessels. Automatic data-logging systems were evaluated and all survey data were teletyped to Ottawa for processing and analysis. The survey demonstrated that automated collecting and processing methods are feasible at the same time as providing useful information on the capabilities of hovercraft-type vessels.

The hydrographic unit of the Polar Continental Shelf Project moved from Mould Bay to Tuktoyaktuk in 1969 in order to begin work in the Beaufort Sea. From March to May 1969 soundings were taken through the ice using a helicopter platform. From early July to mid-September an SRN-6 Hovercraft supporting a strut transducer assembly was used to survey the waters near Herschel Island. Both operations employed a 6F Lambda Decca chain for positioning. The Beaufort Sea offshore survey was almost completed in March and April 1970.

Staff of the Canadian Hydrographic Service continued to support the scientific field activities of the Canada Centre for Inland Waters by establishing field control and operating two Decca Minifix positioning systems, maintaining echo-sounder and sonar equipment and managing the operation of the four ships and 12 launches used by the Centre.

On the West Coast activities continued to be primarily hydrographic, although significant ship and personnel support was supplied to West Coast oceanographic agencies.

CSS *Wm. J. Stewart* continued Minifix-controlled surveys westward in the Strait of Georgia and control was established for the continuation of these surveys northward in 1970. Surveys of Prince Rupert Harbour and of Venn Passage and approaches were completed.

CSS *Marabell* completed a survey of Comox Harbour as well as ranges at Helcken Island and a revisory

survey at Kelsey Bay. In the north, a survey of Port Simpson was made and the Meyers Passage survey was completed. A shore party also completed the survey of Fatty Basin in Barkley Sound for the Fisheries Research Board at Nanaimo.

A revisory survey party aboard the new launch CSL *Revisor* checked 27 charts and surveyed and sounded 14 ranges in the area covering the Strait of Georgia from Sidney to Johnstone Strait and Vancouver Harbour.

Surveys in the western Arctic continued from CSS *Richardson* and CCGS *Camsell. Richardson's* main project was the sounding of a 640-square-mile area north of Kugmallit Bay carried out in conjunction with the Polar Continental Shelf Project whose Decca Lambda chain was used for positioning. The approaches to Paulatuk were sounded and control was extended to the townsite. An investigation was made of Argo Bay. Additional soundings were taken between Cape Parry and Booth Islands and track soundings were run in Darnley Bay and east and north of Cape Parry. *Camsell* ran 1,200 miles of track soundings, mostly in Amundsen Gulf west of Victoria Island in Minto Inlet. Hydrographic work and sounding was undertaken at Sachs Harbour, Jesse Harbour, Coppermine, Expeditor Cove, Bay Chimo, Cambridge Bay, Simpson Strait, M'Clintock Bay, Gjoa Haven, Spence Bay and False Bay in Bellot Strait.

Current surveys aboard CSS *Parizeau* continued in the Strait of Georgia. Three additional cross-sections were observed together with four of the 1968 stations to fill in missing data. Cross-sections from the south end of Texada Island to Point Roberts have now been observed. A current survey using meters and drift poles was carried out off Roberts Bank in participation with personnel of the Pacific Oceanographic Group. Current surveys were made in Vancouver Harbour over the line of the proposed new tunnel crossing at First Narrows. At Victoria, two current meters were placed near the bottom on the proposed sewer outfall extension off Clover Point.

A mathematical model was developed for the Fraser River estuary and is being calibrated. It combines the contribution of tides and runoff and will be designed to provide accurate water-level predictions as an aid to navigation.

A test gauge station was established at Langara Island on the exposed northwest corner of the Queen Charlotte Islands. If this installation withstands the extreme weather and sea conditions it will be linked by radio to the mainland and will become an advanced warning station for tsunamis in the North Pacific.

An evaluation of the Motorola RPS Electronic Positioning System and an investigation of the use of colour and multi-spectra aerial photography and hydrography surveying were initiated.

OCEANOGRAPHY

The Branch provides assistance and expertise where and when required to a large spectrum of Canadian marine activities, which may benefit the economy and resource development, protect the environment or assist in national defence. The services range from the continual provision of tidal and water level data and the archiving and retrieval facility at the Canadian Oceanographic Data Centre in Ottawa, to specific requests and the concentrated effort required when the marine environment is threatened, as in the *Arrow* oil spill. The physical, geophysical, geological and chemical processes governing the marine environment are studied extensively by the research workers in the Branch. The major centres of oceanographic operations and research are situated at the Bedford Institute, Dartmouth, Nova Scotia; at Ottawa; and at Victoria, British Columbia.

The Tides and Water Level Service is probably the most widely used in the Branch, and there was a continuous and increasing demand for information during 1969-70. Data were supplied to many users within and outside the Department. The demand for chart-datum information showed a 70-per-cent increase over the previous year. The new format and bilingual editions of the Canadian Tide Tables have been well received.

The telemetry and announcing networks set up for the West Coast Tsunami Warning System in conjunction with the Department of Transport and Department of Public Works have been working extremely well. Continued instrument development of tsunami and tide gauges is being undertaken and documented.

The Canadian Oceanographic Data Centre offers an automatic processing service for physical and chemical oceanographic station data gathered by Canadian agen-

cies. It is responsible for archiving and the retrieval of these data to meet a variety of needs. In addition, the Centre publishes data reports and continually exchanges data with other national and world data centres. The Centre continued to provide a temporary processing service for Canadian limnological data pending the establishment of a Great Lakes Data Centre.

The data-development section has been largely involved in redefining and improving data handling, the results of which should become evident in 1970.

During the past year the wave-climate study was prepared for the 1970-71 field program by instrument tests and site surveys. An analysis system has been set up for the analogue wave data, the analogue-to-digital software being designed and constructed by a member of the group.

A great deal of emphasis during the past year has been given to organization and establishing a liaison with other federal departments, agencies and branches, and in some circumstances with non-federal agencies. Wave information has been obtained on a regular basis since April 1969 from the Strait of Georgia in a co-operative venture with the British Columbia Research Council. Close liaison has been maintained with the wave-climate study engineers in the Department of Public Works, especially with regard to data requirements. Maintenance of some installations has been undertaken, on contract, by the Telecommunications Branch, Department of Transport, Co-operation with the Division of Mechanical Engineering, National Research Council, led to an intercomparison study of an accelerometer buoy, wave staff and pressure cell in Lake Ontario.

The research group in Ottawa continued its emphasis on mathematical techniques. Tidal motion, wind evaluation and storm-surge problems are analyzed by these methods. Work is nearly complete on a study of the effects of tidal barriers and on how these effects vary critically with only small changes in the exact barrier location. Development is well under way of a wind-driven circulation model of the Bay of Fundy and the Gulf of Maine. It is expected that this work will be extended to include the Scotian Shelf. A steady wind-generated circulation model of the Gulf of St. Lawrence has already been completed and work started on a thermohaline circulation model. A comparison of the wind-driven circulations in Hudson Bay using two different techniques, geostrophic and balance equations, has been accomplished.

Each of the Great Lakes now has a completed wind-generated circulation model, and additional research is being carried out into two-layer and non-linear models. A dynamical storm-surge model for Lake Ontario and a short analytical study on the free oscillation in parabolic and similarly shaped lakes is under way.

A geophysical study of the Chandler wobble of the earth's axis and its relation to mean sea level is partially completed.

At the Bedford Institute the Marine Geology section made a trans-Atlantic cruise in CSS *Hudson* to Lisbon carrying out under way and station work on an 11,000-mile route, including the collection of planktonic foraminifera, deep-sea sediment cores, and drilling to gather rock samples at sea.

In the fall the most ambitious project ever undertaken by the Institute began with the departure of the CSS *Hudson* on the "HUDSON 70" cruise. During her circumnavigation of the Americas the vessel was to carry out multi-discipline studies of the Atlantic, Pacific and Arctic oceans. One outstanding success already accomplished was the first recording of the current structure in Drake Passage between South America and Antarctica.

A submersible was chartered in a joint program with the Biological Station, St. Andrews, N.B. The Atlantic Oceanographic Laboratory used the vessel as an observation platform and for the collection of bottom samples on the sea floor.

A program to map the surficial geology and near-surface structure and stratigraphy across the Scotian Shelf, by sampling and the examination of echo-sounder records, is continuing.

The organic geochemical studies are largely concentrated on an investigation of the role of humic acids in marine sediments. The inorganic geochemistry staff has been developing elemental analyses of fresh and salt water and layering silicates.

The Metrology section is carrying out the development of specialized oceanographic instrumentation. The main efforts of the section have included the successful use

of a rock-core drill driven by the water pressure at depth and the development of a towed "Batfish" which undulates between preset depths and carries instrumentation for the continuous measurement of temperature.

The Air-Sea Interaction research has continued to progress. The major aim of this group is the measurement of the stress of the wind on the sea surface and its equipment and instrumentation requirements are substantial. Good measurements of wind stress were obtained in 1969 before the stable platform suffered storm damage.

Autoanalyzer techniques were to be employed during the "HUDSON 70" cruise for the determination of nutrients especially along the north-south traverses in the Atlantic and Pacific oceans.

In addition to the "HUDSON 70" cruise the Ocean Circulation group continued work on the general circulation and time-dependent motions in the Atlantic and the St. Lawrence estuary. A theoretical study of thermal-convection problems in rotating media is under way.

During 1969 the Marine Geophysics group took part in the CSS *Baffin* Hydrographic-Geophysical survey of the Gulf of St. Lawrence, in a satellite-navigation-evaluation cruise and on a cruise to test the improvement of seismic instrumentation.

The Applied Oceanography section has concentrated its work on investigations in relatively confined waters, including the Strait of Canso, Halifax Harbour, St. Margaret's Bay and the Gulf of St. Lawrence. A study of Long Harbour, Newfoundland, was required as a result of phosphorus pollution.

In February and March 1970, the laboratory was asked for considerable assistance as a result of the grounding of the Arrow in Chedabucto Bay. The Director served as scientific co-ordinator of "Project Oil".

The Frozen Sea Research group in Victoria carried out two major field operations from Greely Fiord, Ellesmere Island, for periods of seven weeks and eight weeks respectively. A variety of measurements and tests were carried out to investigate the water and ice structures and secondary investigations into base operations in this environment were undertaken. The base complex and airstrip are now more or less complete.

Experiments on the freezing of fresh- and salt-water solutions have been carried out in cold rooms at Victoria. These involved measurement of temperature profiles across a growing ice/water interface to a relative accuracy of $\pm .001°C$. The experiments are continuing and are directed towards an expansion in understanding the mechanism of solid/liquid phase change.

The West Coast staff continued the 1968 studies in physical and chemical oceanography and on pollution problems, the latter primarily associated with the discharges of sewage, pulp-mill effluents and wood solids into the marine environment. Most of the studies are carried out in co-operation with other government agencies and with universities.

Physical oceanographic studies in the Strait of Georgia consisted mainly of continuous current observations from moored buoys and drift observations of surface circulations in the Fraser River plume area. A one-dimensional numerical model of the Straits of Georgia and Juan de Fuca was completed and a report prepared.

Three cruises investigating the seasonal and annual variability of the waters up to 200 miles off the British Columbia coast were completed in 1969.

The weathership oceanographic program was expanded to two ships early in 1969. During the May-June cruise of the CCGS *Quadra,* a satellite navigation system, salinity-temperature-depth (STD) equipment, a STD digitizer and a data-acquisition system were all successfully operated. Considerable progress was made in the analyses of both present and past data. For the first time bottom currents have been measured at Ocean Station "Papa" using a free-fall current meter. A buoy program to include current measurements at several depths was begun in co-operation with the University of British Columbia.

Statistical analyses of sea-level data for Tofino, Tasu Sound, Prince Rupert and Bella Bella for May 1962-64 were undertaken. Daily seawater observations were continued at 17 stations, but the laboratory analysis of salinity of seawater samples was restricted to one station only, the remainder recording density by hydrometer.

Oceanographic observations from the drilling rig SEDCO 135F were continued until May 1969, when operations of the rig were suspended.

A numerical study of the effect of winds on flushing mechanisms in Departure Bay and a calculation of the propagation characteristics of tsunamis into all of the major inlets of British Columbia is being pursued.

POLICY AND PLANNING BRANCH

The Policy and Planning Branch advises on and recommends national policy and activities concerning water, air, and the national environment. It helps to co-ordinate federal, interdepartmental, federal-provincial and international activities in use and study of water and air, and advises on the socio-economic impact of such activities.

The Branch consists of three divisions and an administration unit. The library of the Water Sector is also attached to the Branch.

POLICY ADVISORY, CO-ORDINATION AND ADMINISTRATION DIVISION

The Division provides advisory services and the necessary interdepartmental co-ordination for policies and programs related to water and renewable resources. It also provides for federal-provincial consultation and negotiation on river-basin-planning agreements and for the subsequent administration of such agreements. During the year federal-provincial consultations were undertaken with respect to the Saint John River Basin in New Brunswick, the Qu'Appelle River Basin in Saskatchewan and the Okanagan River Basin in British Columbia.

In 1969-70 the Division reviewed, assessed and advised on federal water policies and activities as a basis for drafting new water legislation. In particular, it advised on the drafting of the Canada Water Act, which is designed to initiate and encourage federal and federal-provincial activities for the comprehensive planning, development and management of Canada's major water resources. The legislation places particular emphasis on co-operative federal-provincial programs for water-quality control and pollution abatement.

The Division was frequently called upon to explain federal water and renewable-resources policies and programs to special-interest groups. Also, recognizing the growing pollution of the natural environment and the intimate interrelationship of air, water and soil quality, the Division initiated studies of conflicts between environmental quality and economic growth, and of the various political, legal, and social factors that will have to be considered in the application of the Canada Water Act. Some preliminary work is being carried out by consultants.

The Division provides the secretariat for the Interdepartmental Committee on Resources which, in addition to ensuring a unified federal approach to the work of the Canadian Council of Resource Ministers (CCRM), maintains interdepartmental liaison and co-ordination on matters pertaining to renewable natural resources. The CCRM is composed of eleven Ministers — one from each province, together with the Minister of Energy, Mines and Resources representing the federal government. A co-ordinating committee provides advice and assistance to the Council; the federal representative on the committee is a member of this Division. Among the projects undertaken for this Council was the preparation of papers for and participation in a workshop seminar on water resources in the fall of 1969, the compilation of federal activities in pollution abatement and control, and participation in special advisory groups concerned with pollution, northern development and land use.

Preparations were begun for a major national conference proposed for 1973 on multiple use of resources and conflicts arising therefrom. The Division developed and presented the federal government's recommendations to the CCRM intergovernmental steering committee which was considering common approaches to pollution control by the various levels of government in Canada.

The Division provides the secretariat for the Interim Interdepartmental Committee on Water, which reviews and advises on all federal water policy and programs. The secretariat encourages development of co-ordinated federal approaches through analysis of issues and presentation of alternative solutions. Subcommittees developed proposals for regional water activities in the

Atlantic, Central, Western, Pacific and Northern areas of Canada. Ad hoc committees undertook special tasks, such as drafting a preliminary contingency plan for dealing with disaster pollution; investigating and reporting on water pollution by nutrient materials, particularly by phosphates originating from laundry detergents; and reviewing and assessing criteria by which water-quality standards might be established under authority of the proposed Canada Water Act.

The National Advisory Committee on Water Resources Research, established in 1967, consists of experts from federal and provincial agencies, universities and private industry. The Committee's secretariat is provided by the Division.

The Committee has two subcommittees, one on social sciences and one on natural sciences. Chaired by an official of the Department, the Committee has three functions: to advise the Minister on needs and priorities for water-resources research in Canada, to help co-ordinate such research, and to review and make recommendations on applications for grants in aid of water research and development dispensed by government. In 1969-70 these grants totalled $1,088,855. Development grants to universities totalled $540,000, for natural sciences research, $388,850, and for social sciences research, $160,055.

PLANNING DIVISION

This Division continues to prepare, in co-operation with the provinces, programs of joint comprehensive water-resource plans. It also draws up plans for federal programs for major river basins in Canada. In addition, in anticipation of the forthcoming Canada Water Act, work was under way to assess the organizational and operational requirements for the incorporation of water-quality management agencies and the selection and establishment of priorities for water-quality management areas. Within the joint comprehensive plans a number of water-resource-planning studies are being undertaken and co-ordinated with the federal departments, with provincial agencies, or through consultants. Such studies include the economic, sociological, financial and physical aspects of regional and national water planning. The Division has seven sections: Pacific, Western, Central, Atlantic, General Studies, Resource Data and Water Quality Management.

The Saskatchewan-Nelson Basin Study (SNBS) is a $5-million project shared by Canada with Alberta, Saskatchewan and Manitoba. The study commenced in October 1967 and will be completed by January 1972. Its primary purpose is to appraise the possible sources of additional water supply in the Saskatchewan and Nelson River Basins. The project will also include a preliminary investigation of the works, mainly reservoirs and diversions, required to develop and utilize the water resources of the basins.

During the year about 15 engineering studies were completed for the SNBS concerning water-supply feasibility and estimated cost of many combinations of storage and/or diversion works needed to provide a firm water supply at various selected points along the river system.

River-flow data are being collected and stored on magnetic tape for use in water studies for the SNBS. A number of computer programs have been developed and tested for simulating the operation of water and diversion projects in the basin. Investigations are continuing on operational criteria, constraints on reservoir operation and levels of withdrawal.

British Columbia and Canada are each contributing up to $18 million to the Fraser River Flood Control Program over a ten-year period, May 1968 to May 1978. Joint planning studies include: evaluation of flood-control benefits on the Serpentine-Nicomekl Rivers and on Indian reserves, socio-economic aspects of upstream storage or diversion in the Upper Fraser River Basin and a re-evaluation of overall flood control benefits in the Lower Fraser Valley. The officials are also considering alternative measures of flood control which may ultimately lead to multi-purpose reservoirs and river diversion in the headwaters. Eleven municipalities have made application for assistance in dyking or other projects under the Fraser River Flood Control Program, representing 18 separate projects. A further seven project applications are under review by the provincial government. Soil investigations for nine projects are in final stages of completion. The final design stage for bank protection, dykes and internal drainage has been reached for five projects. Construction is proceeding on two contracts valued at $1 million. Design criteria such as profile and frequency curves for various stations have been completed. Benefit-cost studies are under way for a number of marginal projects. The scope of upstream storage studies is currently under investigation.

The Canada-British Columbia Okanagan Basin Agreement was signed in October 1969, providing for a $2-million program in the Okanagan River Basin, shared jointly with the Province of British Columbia over a four-year period, October 1969 through October 1973. This program includes the preparation of a comprehensive development plan to the year 2020, including consideration of economic growth, water demand, water supply, ecology, aesthetic values, institutional and organizational structures, water re-use and a pilot project for advanced treatment of waste water. Project plans are in the process of being completed for over a hundred tasks including priority setting for the first year of activities.

The Qu'Appelle River Basin Agreement has been drafted and has received the approval of Canada, Saskatchewan and Manitoba. Formal execution of the agreement is expected early in 1970-71. The scope of this project concerns the preparation of a comprehensive development plan, including consideration of water demands, water supply, water quality, lake levels and flooding. The investigations include an economic base study, land use, water quality, hydrology and engineering studies. The $460,000 cost of the study will be shared jointly with the provinces of Saskatchewan and Manitoba over a two-year period, March 1970 through March 1972. Several ad hoc meetings have taken place prior to the setting-up of a study board and the appointment of a study director to discuss investigations and studies.

A task force has been set up for preparing a comprehensive framework plan for the development of water and related resources of the region embracing Lake Winnipeg, the Nelson River, the Saskatchewan River east of Cumberland Lake and the Churchill River Basin. It will also evaluate in greater detail proposals for regulation of Lake Winnipeg and diversion of water from the Churchill River into the Saskatchewan and Nelson Rivers. The task force report is expected to be submitted by June 1970.

An ad hoc task force has been formed to prepare background papers and briefing notes on the Great Lakes for future meetings between the federal, provincial and U.S. governments to discuss International Joint Commission report recommendations and common water-quality and pollution problems.

The Saint John River study of three-year duration will last from June 1970 through June 1973, at a cost of $775,000. The scope of this agreement with the Province of New Brunswick covers the preparation of an interim water-quality plan to be followed by a comprehensive planning program including consideration of water demand, water quality, water supply, ecological and aesthetic values, institutional, legal and administrative structures, and international implications. Background work undertaken this year includes the composition of a federal-provincial board and committee, preparation of the final draft agreement and designation of task teams to evaluate previous projects carried out by consultants.

Northeast New Brunswick Mine Water Quality

A proposal by the Federal Department of Fisheries and Forestry to set up a task force to investigate the pollution by mining wastes of northeastern salmon rivers in New Brunswick was under consideration by the Canada-New Brunswick Consultative Committee.

A review of provincial priorities and coastal and harbour pollution problems was initiated by the Canada-Nova Scotia Consultative Committee. A federal-provincial task force has been set up to report on water-resources problems and make recommendations for co-operative action.

Resource Data Section

This section is in the process of setting up a basis for the collection, categorization, storage and retrieval of information and data to help the water resource planning of the Division and Branch.

General Studies Section

Technical assistance and support is provided on a continuing basis to the regional units in the areas of economic analysis, new planning techniques development and other special assignments. A major program is under way to assess the National Water Use and Demand projections broken down by regional areas and by consumable and non-consumable use categories.

RESOURCES RESEARCH CENTRE

The Resources Research Centre conducts socio-economic research on the management of water and renewable resources and the protection of the environment.

The Centre comprises four sections: Economic Geo-

graphy, Resource Management and Special Studies in Ottawa, and the Great Lakes Section at the Canada Centre for Inland Waters (CCIW) at Burlington, Ontario. In addition to these sections, the Centre provides the secretariat for two geographical committees.

The Economic Geography section has experience in land-use planning, resource-use assessment, cartography and geographical aspects of regional urban and environmental problems.

The section's activities may be classified in three categories: 1) studies requested by other federal and by provincial government agencies, 2) studies requested by other divisions of Policy and Planning Branch, 3) studies initiated within the Centre.

Land-use maps of populated areas of eastern Canada (east of Manitoba) were completed for the Canada Land Inventory on behalf of ARDA early in 1970. The major portion of the study was begun in 1963 and finished by 1968, but completion of the entire project was not possible until air photos of Newfoundland were available. Other projects undertaken for the Canada Land Inventory were a land-use study of the Musquodoboit Valley, Nova Scotia, and the Prince Edward Island Development Plan.

Land maps of the Halifax-Dartmouth area were begun for use in urban planning by the Nova Scotia government.

Preparations were made for a study of the socio-economic implications of resource development in the Northwest Territories and the Yukon. This study will result in the establishment of land-use regulations.

Two projects related to river-basin planning were started. The first is evaluation of benefits to agriculture of proposed flood control on the Serpentine and Nicomekl Rivers in support of the Fraser River Flood Control Agreement with British Columbia. The second is a topographical relief map of the Okanagan River Basin showing its land relief, which is essential to water management.

A Great Lakes section was established about mid-year at the CCIW at Burlington, Ontario. Its responsibilities include:

(a) conducting social research focussing on the Great Lakes Basin, and

(b) providing advice to the CCIW on relating its natural-science research to the overall priorities of federal water policy.

Projects already begun include a water-use map of the Great Lakes, the economics of waste disposal, application of data to an economic model and a public perception and attitude survey designed to determine public awareness of pollution issues.

The Special Studies section concentrates its activities in two major areas:

(a) basic research to support the primary objective of the Centre in emphasizing the human aspects of resource and environmental issues, and

(b) research to provide a long-term perspective on future priorities for public resource programs.

The section is in the early stages of development.

The major current activity of this section is the pilot study on the Saint John River, which is one of Canada's contributions to the program of the NATO Committee on the Challenge of Modern Society. This three-year project is in the planning stage. Its primary objective is to develop and evaluate techniques of generating public participation in planning water-resource development, according to the economic and social needs of the affected population.

The Resource Management section is also in the initial stages of development. It is proposed that the staff of the section be a small but highly skilled group concerned with the application of social science on a foundation of natural science.

The Saint John River Simulation Model study was begun in February 1970. This study will include a set of engineering-economic models from which the optimum plan for water-quality management may be determined.

Planning has also begun for an international symposium to be held in 1972, during which mathematical models proposed for water-resource systems will be discussed.

In resource technology, studies are being developed in several fields. A study of air-photo interpretation and flooding has been started, and publication of a handbook for flood plain and water-resource planning is expected by mid-1971.

In addition to the above section, the Centre houses the Geographical Secretariat. The Secretariat administers the affairs of two committees:

(a) The National Advisory Committee on Geographical Research, and

(b) The Canadian National Committee of the International Geographical Union.

One of the Secretariat's major current responsibilities is the preparation and organization of the 22nd International Geographical Congress to be held in Montreal in 1972.

INLAND WATERS BRANCH

The Inland Waters Branch is the federal agency which provides services in natural sciences and engineering for optimum management of Canada's water resources. It produces scientific and engineering data, research results, and engineering studies, appraisals and advice.

One of the Branch's major objectives is the collection and dissemination of information on water quantity and quality throughout Canada. This is being achieved through networks of observational and sampling stations on Canadian rivers, lakes, aquifers, glaciers and snow courses. Emphasis is placed on making the collected data readily accessible in the most usable form.

Also of major importance is the Branch's responsibility for providing to the Government of Canada advice on technical aspects of managing interprovincial and international waters. This takes the form of technical studies in support of international and federal-provincial programs and agreements relating to fresh water.

To ensure that Canada's water resources are being used wisely for the benefit of present and future generations, new concepts have had to be developed and new knowledge of the behaviour and occurrence of water in the hydrologic cycle acquired. Standards and procedures for improved regulation and use of the country's fresh-water resources will have to be devised, and methods for predicting the response of lakes and rivers to pollution as a basis for economic pollution control must be developed. Liaison with other government agencies, universities and industries must be fostered both nationally and internationally for exchanging knowledge in the water field. These are the chief objectives of the Inland Waters Branch in its endeavour to provide the Government of Canada with the information essential for the development and application of an effective national water policy.

The Branch undertakes a major publication program to make its scientific and engineering data and studies available to the technical community. During the past year more than 100 scientific or technical brochures were published by the Branch and numerous papers were published in scientific journals.

CANADA CENTRE FOR INLAND WATERS

The Centre was established in 1967 at Burlington, Ontario, as a new federal institution for water research. The Department of Energy, Mines and Resources, mainly through its Inland Waters Branch but assisted by the Marine Sciences Branch and the Policy and Planning Branch, co-ordinates the activities at the Centre in collaboration with the Fisheries Research Board, the Department of National Health and Welfare, and the Association of Universities and Colleges of Canada.

The Centre is presently housed in a 25,000-square foot trailer complex, an assortment of temporary buildings, which provide housing for laboratories, stores, workshops, and library, and office space for administration, scientific and technical services. During the year, site development for the principal buildings were well advanced. Construction of the warehouse and workshop, the first permanent building, was begun in 1969. Construction of other buildings is expected to commence at brief intervals.

A number of important developments occurred during the year at the Centre. Volume 1 of the Report to the International Joint Commission on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River was released in October. Much of the Canadian survey work for that report was carried out by the staffs of the agencies associated with the Centre who collaborated with their colleagues of the Ontario Water Resources Commission, other federal agencies and United States representatives. Aside from recommending ways to control pollution, the report defines several problem areas which are under study in special research programs at the Centre.

At year's end, the federal government's contingency plan for dealing with major spills of oil and toxic material in waters of federal jurisdiction, co-ordinated by the Centre, was submitted to the Interdepartmental Committee on Water. The Committee approved the plan and recommended that it be submitted for Cabinet approval. A Socio-economic unit from the Policy and Planning Branch was established in November to undertake research in economics, sociology and geography complementary to existing research in natural science. A Public Relations and Information Services unit was established. An Environmental Quality Co-ordination unit was established in June to co-ordinate the results of research from the various disciplinary groups of the Centre and to channel those results into reports aimed at pollution abatement. A consultant's report on thermal inputs to the Great Lakes was released and further studies of the temperature and ecological effects of projected waste-heat discharges are under way. Work is under way to appraise potential environmental effects of "NTA", currently the most probable substitute for phosphates in detergents, and to study the distribution of mercury and other toxic materials in the sediments of Lakes St. Clair and Erie. At the annual Great Lakes Conference of the International Association for Great Lakes Research in Ann Arbor, Michigan, the 17 scientific papers presented by the Centre's staff formed the largest contribution from any research centre.

WATER SURVEY OF CANADA

The Water Survey of Canada conducts systematic surveys of stream-flow, water levels and sediment transport throughout Canada and publishes the results annually. In addition it carries out snow and glacier surveys. The Water Survey is also expanding its survey network to collect field data on behalf of other departmental agencies. During danger periods on a number of rivers subject to floods, a flood-warning service is maintained in co-operation with the provinces concerned. Although all of these activities are designed to meet the requirements of the federal government, an increasing portion of the total effort is aimed at satisfying needs of the provinces.

The Water Survey and its predecessors have collected and published basic streamflow and water-level data on a national basis for more than half a century, while the sediment survey has been in operation since 1961. These surveys are being expanded steadily and at present are conducted from 30 district and field offices extending across Canada. Planned expansion in 1970 will see a new district office established at Regina to serve the province of Saskatchewan and a new sub-office in the Atlantic provinces to better serve the province of New Brunswick. Two additional district offices in the north are to be established to provide closer liaison with agencies in the Northwest Territories and the Yukon Territory.

In 1964, the Quebec Department of Natural Resources assumed responsibility for the collection of hydrometric data for most rivers in Quebec; however, collection of data for a number of navigable and international streams in Quebec remains the responsibility of the Water Survey.

During the year under review some 50 stations were added to the Water Survey's gauging network, bringing to approximately 2,300 the total number of streamflow and water-level stations. Sediment data are gathered at 98 of these stations, an increase of 16 stations during the year. The above total also included 131 water-level stations operated in the field for the Tides and Water Levels section of the Marine Sciences Branch; most of these stations are located in the Great Lakes-St. Lawrence River system. The Water Survey also participates in the collection of hydrologic data for some 40 research watersheds established for the International Hydrological Decade.

During the year, hydrometric network planning, aimed at providing a sound basis for further expansion, was continued by engaging a consultant for planning the Prairie provinces, British Columbia and Northern Canada networks. By agreement with the Department of Indian Affairs and Northern Development (IAND), the Water Survey of Canada carries out the hydrometric

surveys in the Yukon and Northwest Territories; the Water Survey also collaborates with IAND in assessing the water resources in these areas.

Intensive sediment surveys on the lower Fraser River continued so as to provide data essential for the maintenance and improvement of the navigation channels in the river. Similar work on the south Saskatchewan River is under way to determine the effect of sediment deposition in Lake Diefenbaker and degradation in the river downstream from the dam. A terrestrial photogrammetric study to determine the extent of shoreline erosion of Lake Diefenbaker was also undertaken. A survey and study of reservoirs in Ontario was undertaken to determine the sedimentation regime and the extent of shoreline erosion. In applied research, the Water Survey helped develop new equipment and techniques for the measurement of sediment transport, particularly bed-load movement.

Automatic data processing was initiated in 1966 when two major projects were undertaken — the storing of historical hydrometric data on magnetic tape, and the developing of automated procedures for the computation of current data. Approximately 33,000 station-years of record, representing all historical daily-discharge data to 1968 inclusive, have been key-punched and converted to magnetic tape, and are available for computer processing. Special equipment for digitizing charts to develop automated streamflow computations has been installed and is now operational in all districts across Canada.

Engineers of the Water Survey of Canada are members of, or participate in, the activities of some 20 engineering boards, committees and special studies in connection with various aspects of national, international and inter-provincial water problems. These responsibilities include major streamflow measurements on the interconnecting channels of the Great Lakes, on Northern Ontario rivers and on the Nelson River.

HYDROLOGIC SCIENCES DIVISION

The Hydrologic Sciences Division studies the physical processes governing the behaviour of water in the hydrologic cycle to improve methods of water management. In addition, it takes part in such research as the International Hydrological Decade and the International Field Year on the Great Lakes, and enters into joint research with universities, provincial authorities and other government departments and agencies in order to increase our understanding of the basic process of the hydrologic cycle, with particular emphasis on Canadian situations and applications.

The Division consists of three operational subdivisions — Glaciology, Groundwater and Water Science. The Division also provides administrative services required by the Secretariat of the Canadian National Committee of the International Hydrological Decade. Design specifications for a hydraulics laboratory to be located at the Canada Centre for Inland Waters to study the behaviour of moving water under environmental conditions are nearing completion, and construction is expected to start in 1971. Hydraulics staff will move to the Centre in mid-1970, and the Hydraulics Division will be established as a separate entity in April, 1971.

Glaciology Subdivision

Annual mass-balance measurements on Per Ardua Glacier (Ellesmere Island), Decase Glacier and the Barnes Ice Cap (Baffin Island), continued, and further support was given to glaciological work on the Devon Island Ice Cap.

Movement studies on the Barnes Ice Cap continued, and terrestrial photogrammetry was used experimentally in mass-balance studies on White Glacier, Axel Heiberg Island.

Theoretical work on the macro-scale climatology of the Arctic regions continued, with emphasis on moisture-flux distribution.

Work was begun on a new study of the distribution and rate of iceberg production from Canadian tidewater glaciers. Studies were intensified on hydrologic problems in Arctic Canada, with emphasis on the Mackenzie Delta.

Collection continued of annual mass-balance data for representative glacier basins in western Canada and the eastern Arctic, together with water-discharge measurements and meteorological observations. In addition, photogrammetric measurements were made at selected basins in order to determine glacier movement.

Parametric and statistical models of glacier melt were prepared for Peyto Glacier, Alberta, and a hydrologic

model is to be compiled for a more extensive basin. The model will be applied to melt water from ice and snow in the headwaters of the North Saskatchewan River, and should lead to more accurate forecasts of runoff from Alpine areas and glacierized basins.

Determination of the energy balance over the ice surface of Peyto Glacier will aid in the assessment of the components of ice and snow melt. A well-instrumented experimental plot was established at a site near Ottawa to study snow metamorphosis, snow melt and associated changes in soil moisture content and groundwater levels.

Development work and field testing of a 620-MHz radio echo-sounder for determining glacier thickness, continued in co-operation with the Water Science subdivision.

Preparation of a shaded relief map of Peyto Glacier, Alberta, continued in co-operation with the National Parks Branch, Department of Indian Affairs and Northern Development. The back of the map sheet will have an illustrated text containing historical, geological and other information of interest to tourists.

A glacier inventory of Axel Heiberg Island, N.W.T., has been completed. An index of over 12,000 glaciers on Baffin and Bylot islands has been prepared; these glaciers, plotted to a scale of 1:500,000 on 25 map sheets, will be published in an atlas. An inventory of glaciers in the Rocky Mountains and on Vancouver Island is being compiled; and a start has been made on survey of iceberg-producing glaciers in the Canadian Arctic.

The Science section published the first results of the X-ray topographical study of dislocations in ice, and further work is in progress. A postdoctoral fellow completed a two-year study of the effect of impurities on the mechanical properties of ice crystals.

A theoretical study of the possible future behaviour of Berendon Glacier, B.C., was completed and submitted for publication.

Groundwater Subdivision

The Maritime Research section which came into operation in 1969 already has made substantial progress. The section has undertaken to obtain information on seawater intrusion into coastal aquifers, to develop hydrochemical pumping-test techniques for coastal well fields and geophysical methods for studying groundwater flow in fractured rock. By the end of the current year, geophysical techniques had successfully located fresh and saline groundwater along the coasts of Prince Edward Island and New Brunswick. Moreover, new methods have been developed and are being tested to determine aquifer properties by hydrograph analysis, thermal logging and fracture analysis.

Computer-drawn maps showing various groundwater parameters in the Lake Ontario drainage basin have been produced by the groundwater-data-storage system (GOWN) from data for 60,000 wells supplied by the Ontario Water Resources Commission. These maps will be used during the International Field Year for the Great Lakes. Analysis of streamflow for 18 rivers flowing into Lake Ontario and estimation of groundwater flow into the lake have also been completed.

Other noteworthy items are the completion of runoff computation for 36 sub-basins of the Fraser River using parametric models, the use of microfaunal assemblages to determine past physical and chemical environments of prairie sloughs, and the development of a new technique to estimate regional evaporation. The inventory of Canadian freshwater lakes has been completed and published in atlas form. It is a first step in determining the quantity of water in storage in Canada.

Water Science Subdivision

The past year has seen the instigation and expansion of a large number of projects in the Water Science subdivision, which is responsible for providing the basic chemical and physical knowledge essential for the best utilization of Canadian water resources.

Studies of the physical properties of solutions are aimed primarily at determining the variation in parameters of pollutant solutions as a function of temperature, pressure and concentration.

Determinations of the mobility, degree of hydration, structure, conductivity and dielectric properties of solutions containing nitrates, phosphates, halides and heavy metal ions were carried out. The rate of reaeration through the surface of stagnant water bodies is being studied; and the effects of surfactants and pollutants on the reaeration rate are being evaluated. Molecular orbital calculations are also being used to aid in understanding the nature and hydration of dissolved gases and sulphurous compounds in water.

Toxic compounds in water are being studied with various techniques. These include X-ray crystallography of the crystalline compounds to elucidate their structures and the structures of products formed by their reaction with water, adsorption studies to show the rate and mechanism of their removal and co-ordination studies to show how such materials may form compounds in nature.

The Instrument Development section has continued to maintain and repair existing equipment as well as modify and design new equipment for the other subdivisions within the Hydrologic Sciences Division. A major project in this section is the development of a radio echo-sounder for locating and improving our understanding of the bottom profile of glaciers. This project requires the accumulation and handling of large amounts of data.

Future plans for the Water Science subdivision include the establishment of a Biosciences section to deal with the many aspects of water and its interactions with naturally occurring biota.

International Hydrological Decade Secretariat

The Secretariat's duties are guided by the 26-member Canadian National Committee which co-ordinates the country-wide scientific investigation and assessment of water resources under the International Hydrological Decade.

The Secretariat continued its active role in co-ordinating and reporting on the 185 active, ten deferred and 26 completed projects included in the Canadian program.

In addition to co-ordinating the program through the co-operation of various federal, provincial and university representatives, and organizing the annual meeting of the Canadian National Committee, the Secretariat organized, in co-operation with the University of Manitoba, an extensive hydrology seminar for Canadians; two workshop seminars — one on hydrologic mapping (resulting in a publication) and one on representative basin review; it met Canada's international IHD commitments through co-operation with UNESCO and the World Meteorological Organization, and provided assistance to federal, provincial and university agencies involved in holding seminars and workshops in hydrology. Detailed planning is under way for a CNC-sponsored international symposium on the role of snow and ice in hydrology, to be held at Banff in September 1972.

The Secretariat also published the annual progress report on Canadian IHD research projects and some preliminary surface water maps for the Hydrological Atlas of Canada.

GREAT LAKES DIVISION

The Great Lakes Division seeks to provide the knowledge and understanding of the chemical, physical and sedimentological behaviour of Canadian lakes needed for optimum management of the lakes. This task encompasses all Canadian lakes, but the emphasis at present is on the Laurentian Great Lakes because of their economic importance.

The Division conducts applied research and collects scientific data, and engages in limnological instrument design, development and evaluation, augmented by basic research. It encourages and promotes Great Lakes research in Canada and plays a leading role in co-ordinating research and data collection with its counterparts in the United States. Scientific support as well as administrative and technical services are provided to the various divisions and agencies at the Canada Centre for Inland Waters.

The Division's principal responsibilities are carried out by the Physical Limnology, Chemical Limnology and Limnogeology sections. However, aside from providing programmer services, the Computer and Data Services section maintains a computer terminal at the Centre and is testing shipboard computers. The Engineering Systems section provides engineering services to all sections and agencies at the Centre and to the scientists of the Association of Universities and Colleges of Canada participating in programs of the Centre. Personnel from the Technical Operations section are assigned to ships monitoring the Great Lakes and carry out all deck observations and routine meteorological observations.

Physical Limnology Section

The section conducts research into the hydrodynamic and the thermodynamic behaviour of lakes, undertakes studies of applied limnology and provides climatological and descriptive services in various aspects of physical limnology.

During the year, data collected during 1967 and 1968 in the Niagara River Plume studies were used to study circulation, thermal and diffusional characteristics of the Niagara River effluent. In air-lake-interaction

studies, special data collected during 1967 near Burlington and during 1968 near the mouth of the Niagara River were analyzed.

The 1969 MELON (Massive Effort in Lake Ontario) experiments were designed mainly to examine the structure and variability of water movements in the western end of Lake Ontario. The core of the experiments consisted of arrays of moored, self-recording current meters; but drogue tracking and dye-patch diffusion experiments were also employed. Airborne-remote-sensing techniques mainly in western Lake Ontario have also provided data which have been incorporated in the MELON program.

The preparation of an atlas of Great Lakes data continued. Summaries in map form of all available temperature and dissolved-oxygen data should be completed by the end of 1970.

The section collaborated with others at the Centre in the Fisheries Research Board's small-lakes-eutrophication program near Kenora, Ontario. In other areas, it has been involved in the design, development and testing of instruments and related equipment, in investigating, testing and evaluating models of hydraulically induced circulation, and has reviewed current methods of combatting oil pollution.

Chemical Limnology Section

The section is responsible for the planning and evaluation of the chemical monitor cruises on the Great Lakes. During the past year, a considerable part of the section's effort was diverted from purely laboratory studies to field studies, notably in co-operation with the MELON program.

Lake Ontario was monitored intensively during 1969, with cruises being scheduled every four weeks during the year while only one or two cruises were carried out on the other lakes.

During the year, personnel co-operated in a Lake Erie Time Study (LETS) to determine the extent and time duration of short-lived chemical and biological phenomena such as algal blooms in the lake's western basin. Rain samplers were installed at several stations on the Canadian shore of Lake Ontario to assess the contributions to the chemical budgets of the lake from atmospheric sources. Instruments were acquired to separate dissolved organic material extracted from lake water into individual compounds. Equipment was under test to determine the surface area of sediments, a property which reflects the ability of such deposits to absorb organic matter. Analyses of the interstitial water in sediment cores, sampled at uniform intervals at several stations in western Lake Ontario, revealed little variation in the chemical properties of the sediments over the summer. Studies of the geochemistry of brines were undertaken with a view to increasing our knowledge on the formation of sulphate-rich lake brines and prediction of the precipitation of sodium sulphate minerals. Micro-analytical methods for determination of molybdenum and vanadium in lake water have been developed and studies of these elements in lakes are in progress. The phosphorus cycle of Lake Ontario has been under study to determine the relative size and importance of, and seasonal changes in, the soluble organic phosphorus fraction in western Lake Ontario waters. Studies under way are concerned with the measurement of thermodynamic properties of aqueous mixed-salt solutions in the temperature range from the freezing point to 25°C. A program carried out on Lake Ontario during 1969 has led to the development of a technique for measuring the "rate of fall" and the "settlement rate" of organic particles in the water column. These and many other studies are adding to our understanding of the ecology and are revealing those areas requiring more effective water management practices.

Limnogeology Section

The section is undertaking two different though interrelated types of research on the bottom sediments and suspended particulate matter of major Canadian lakes. In one, inventory data are obtained which will permit categorizing and plotting of distribution maps and diagrams, to show, for example, what types of material are present in the lake sediments, how much material there is and where it occurs. The second line of research includes studies of the physical problems of erosion, transportation and deposition of sediments, the organic and inorganic chemical processes that took place within the sediment between the time of deposition and solidification, and the various geobiological inter-actions between the sediments and the biota. Of particular importance are exchanges of phosphates and other nutrients and micronutrients between the sediments and the overlying waters.

Major surveys consisted of: a sediment inventory along the north shore of Lake Ontario; collection of 560 bottom samples and cores in the heavily polluted

Niagara River mouth area and in relatively clean Georgian Bay - Bruce Peninsula region to provide valuable information for process studies on the spatial variations of physical, chemical, and biological parameters within the sediments; in the area of Lake Ontario between Hamilton and Toronto variations in the textural and mineralogical characteristics of sandy sediments were used as natural tracers to determine the net direction of transport and the origin of nearshore sand deposits; a number of different species of chironomids were taken from bottom samples from Lake Ontario in order to read them for morphological observations and identification at different stages in the life cycle (chironomid distribution is related to the degree of pollution of the sediments and can, it is hoped, be used as an indicator organism); detailed continuous profiling surveys were run over much of the western basin of Lake Erie, designed for shallow penetration to provide a better understanding of the complex stratigraphy of the unconsolidated deposits; a seven-week sediment cruise of Lake Huron was undertaken during which 7,000 nautical miles of line were surveyed and bottom samples were obtained at 196 stations for geochemical and sedimentological analysis.

In addition to these major projects, a team of divers undertook a preliminary evaluation of underwater sampling and survey operations using an underwater habitat located on the Bruce Peninsula. On Lake Winnipeg, a co-operative program was carried out with the Fisheries Research Board involving comparative tests using different bottom sampling and coring devices to determine the most efficient equipment for obtaining biological and geological materials.

Laboratories of the section have continued to process samples and to develop new methods for quantitative and qualitative geochemical and sedimentological analyses of sample material.

ENGINEERING DIVISION

The Division conducts field and office engineering investigations and makes recommendations on the development of water resources. It establishes ranges of engineering costs and prepares estimates of benefits for developments such as hydro-electric power plants and water-supply systems for domestic, industrial, irrigation or other uses. The Division provides technical advice to various federal and provincial departments and agencies; examines and reviews proposals for water conservation and control, including hydrology, hydraulic and structural design, and comparison of project benefits and costs; maintains continuing inspection and review of water-conservation and control projects to which Canada is contributing financially; undertakes negotiations with respect to federal participation in water projects and participates in federal-provincial and international boards, committees and task forces established for water-resource investigations, development, control and regulation.

To cope with its manifold tasks, the Division has four regional sections — Atlantic, Central, Western and Pacific — engaged in country-wide investigations and studies. Four support sections provide services in engineering hydrology, field investigations, project design and appraisal, and engineering systems to the regional components. Except where specifically noted, the Division's staff is located in Ottawa.

Engineering Hydrology

Engineering-hydrology studies carried out in the Division may be grouped into three broad categories: 1) those required in support of international, federal-provincial and federal programs pertaining to fresh water; 2) those which contribute to the general knowledge of Canadian water resources; and 3) those of a basic nature for the development of improved methods of hydrologic analysis. Examples of these three types of studies carried out during the year are as follows:

1) At the request of the Department of Transport a study of the Trent Canal system was undertaken. This study resulted in a set of tables for use in the day-to-day operation of the canal system between Hastings and Lake Ontario. These tables give all of the required relationships between flow, water level, gate openings, backwater, time of travel and changes in reservoir storage.

2) A brochure entitled High Water on Lake Winnipeg was issued for public information. This brochure gave a factual presentation of the factors causing high water on Lake Winnipeg, with particular reference to the maximum recorded level of 1966. The main purpose of the brochure was to correct some of the ill-informed opinions that had been voiced as to the cause of flooding on the lake.

3) Research was carried out on the analysis of floods, annual flows and monthly flows.

Field Investigations

The Division carried out the fourth year of field and office work investigations on the cost and engineering feasibility and of water-resources development in Northern Ontario. Field work was virtually completed, but preliminary design and costing of structures for alternative schemes are continuing and reports on water yield, power potential, cost and physical benefits for alternative development possibilities are under preparation.

Project Design and Appraisal

The Canada Water Conservation Assistance Act empowers the Government of Canada to provide financial assistance to the provinces in the construction of major works for the conservation and/or control of water. During the year the Division provided technical assistance in the design and appraisal of projects implemented under the Act. Activities were concentrated on conservation and flood-control works for the Metropolitan Toronto and Region Conservation Authority, Upper Thames River Conservation Authority and the Halton Region Conservation Authority in Ontario, and on projects in north and west Vancouver and in Alberni in British Columbia. In Manitoba, similar service with respect to construction of the Red River Floodway was provided under an ad hoc agreement. This major project was placed in operation during the year; however, several minor items are yet to be completed. Under a similar agreement, technical assistance was provided for the construction of flood-control dykes around several communities in the Red River Valley.

The final draft of the manual of standards and procedures for planning water-resources projects in Ontario was completed under the aegis of the Canada-Ontario Committee on Canada Water Conservation Assistance Act Programs and technical advice was provided on the assessments of discharge records to the Lake of the Woods Control Board.

The Division prepared up-to-date capital-cost estimates for the reconnaissance survey of hydro-electric potential in the Upper Yukon River Basin, and examined alternative schemes of development.

Engineering Systems

The Engineering Systems section was formed in July 1969. The main functions of the section are to develop mathematical modelling and computer applications for water engineering.

Work was completed during the fiscal year on a contract with the Saskatchewan-Nelson Basin Board to develop a mathematical model to produce synthesized flow sequences at 13 points in the Saskatchewan-Nelson Basin. The section also participated in studies by the International Great Lakes Levels Board and the International St. Lawrence River Board of Control.

Pacific Region

The Pacific Regional Office in Vancouver, British Columbia helps to carry out the ten-year federal-provincial Fraser River flood-control program which was authorized by Agreement in 1968. The regional engineer serves in alternate years as chairman and as vice-chairman of the Fraser River Joint Program Committee. Staff of the Division co-operated with provincial-government engineers and worked with consultants to develop design criteria and designs for dykes, pumping installations, river-bank stabilization and internal drainage works in the Lower Fraser Valley.

A section of the staff provided engineering support to the chairman of the Canadian section of the Columbia River Treaty Permanent Engineering Board. The regional engineer served the Canadian section as alternate member to the chairman and as secretary. The staff analyzed flood-control and power-operating data, prepared reports on implementation of the treaty and on operation of the treaty storages, and reviewed technical reports and operating programs prepared by the various agencies involved. The staff also continued to provide engineering support to the chairman of the Federal - Provincial Columbia River Advisory Subcommittee.

The regional staff participated in several other projects, including evaluation of the Upper Yukon River power-market potential.

Western Region

Excellent progress was made on the Saskatchewan-Nelson Basin study which is an examination of the water resources of the Saskatchewan-Nelson Basin, including potential additional supply by diversion or storage. The study is under the direction of the Saskatchewan-Nelson Basin Board, whose secretary is an officer of the Division. The staff also undertook

the preparation of a report on effects of southward diversions on the Athabasca-Mackenzie System.

The Prairie Provinces Water Board was reconstituted and an agreement apportioning the waters of the three prairie provinces was signed by Canada and the provinces of Alberta, Saskatchewan and Manitoba. An officer of the Division has been acting as *pro tem* secretary to the reconstituted Board pending establishment of a permanent secretariat.

The Division also provides the secretary and engineering support for the Canadian section, International Souris-Red Rivers Engineering Board.

Central Region

Through its Central Region section, the division provides advice on the regulation and control of waters of the Great Lakes - St. Lawrence system and carries out studies related to water management in the region. An office is maintained at Cornwall from which the regulation of Lake Ontario is supervised by Division members representing the International St. Lawrence River Board of Control under the aegis of the International Joint Commission. During the past year, the office staff contributed to studies of problems caused by low water levels on Lake St. Lawrence and of the problem of timing the installation of the ice-control structures in the International Rapids Reach.

The Division also provides technical advice to several other boards established by the Commission. As part of its responsibilities for regulating the outflows of Lake Superior, the International Lake Superior Board of Control made provision for the storage of additional water in the lake during the latter months of 1969, for release during the winter; this action was taken in connection with a test by the International Great Lakes Levels Board aimed at determining the feasibility of increasing maximum winter outflows.

Technical assistance was also provided by the Division to the Commission's American Falls International Board and its International Niagara Board of Control. As part of the investigation of the American Falls Board into possible measures to preserve and enhance the beauty of the American Falls, the Board temporarily dammed up the American Falls Channel during 1969 in order to permit intensive field surveys and geologic studies to be carried out "in the dry".

During the year, a high priority was given to studies for the International Great Lakes Levels Board of the Commission concerning the feasibility of further regulating any or all of the Great Lakes. Preliminary results have been obtained with regard to possible benefits from further regulation. The studies take into account the effects of varying lake levels and outflows on the various shore properties, navigation, and power production.

Atlantic Region

The Division provides technical advice with respect to the management of the water resources of the Atlantic provinces.

The study of the feasibility of building tidal-power plants in the Bay of Fundy was completed during the year. The Engineering Division provided technical and related support to the Atlantic Tidal Power Programming Board, which carried out the study under an agreement among the governments of Canada, Nova Scotia and New Brunswick. An officer of the Division acted as secretary to the Board and to the Board's Associated Engineering and Management Committee.

During the year the second phase of the study was completed. This work consisted of a refinement of the design and construction concepts for proposed structures, analyses of the possible power output and available markets as well as economic analyses of the power and energy products of such tidal power schemes.

WATER QUALITY DIVISION

The Water Quality Division collects, interprets and disseminates water-quality data for inland and coastal waters in Canada, conducts applied research in water and wastewater treatment and in analytical methodology, and provides analytical laboratory support for water-resources research and field investigations undertaken by the Department and by other government agencies, the provinces, universities, and private institutions.

The Division is divided into three subdivisions; 1) Resources and Surveys, 2) Water Pollution Research, and 3) Water Chemistry. Laboratories are maintained at Ottawa and Burlington, Ontario; Moncton, New Brunswick; and Calgary, Alberta.

Resources and Surveys Subdivision

The Resources and Surveys subdivision, which collects, interprets and disseminates water-quality data, continued to expand the monitoring and surveillance network across Canada to provide baseline water-quality data and measurement of pollution effects. Approximately 550 permanent sampling stations were in use during the year, an increase of 280 from the previous year. Emphasis continued to be placed on the establishing of sampling stations at gauging stations which are operated by the Water Survey of Canada, particularly in waters in which there is a strong federal-provincial interest. Sampling frequency varied from daily to monthly, depending on the accessibility of the stations and on the requirements of other studies of the sampled waters.

The expansion of the network in the Okanagan Valley is particularly noteworthy, as it illustrates one form of joint federal-provincial collaboration foreseen under the Canada Water Act. During the early planning of a Canada-British Columbia comprehensive study of the Okanagan Basin, the Division expanded the network of stations in the valley from four to 45, and began assembling water and wastewater quality data for the forthcoming study.

The Division also participated with other federal departments and provincial agencies in the planning and operation of a network of sampling stations in the Prairie provinces establishing the extent of mercury pollution in major waters in that area. The measurement of mercury concentrations at representative stations elsewhere across Canada was added to other routine analyses to provide data on this widespread contamination.

Collaboration continued with other government departments, provincial agencies and universities on research and experimental river basins throughout Canada, and the Department's work in the International Hydrological Decade, as did the water-quality study of the headwaters of the Saskatchewan River system, in support of the Eastern Slope watershed program.

The selection, acquisition and delivery of eight robot water-quality monitors for the Atlantic provinces was completed toward year-end. Plans were finalized for the location of seven monitors on the Saint John River and its tributaries in New Brunswick, with installation to be completed in 1970. The installation of the monitors represents a milestone in network development in Canada, making it possible to automatically measure and record stage, temperature, pH, turbidity, conductivity, chloride and dissolved oxygen at each station at hourly intervals, with all data telemetered to Moncton for reception and recording. The eighth monitor is to be located on the Petitcodiac River at Moncton. Each monitor is housed in a trailer providing not only mobility but also a field laboratory.

Monitoring of water quality in streams in the base-metal mining area of New Brunswick continued in support of pollution-control studies by the Department of Fisheries and Forestry and by the New Brunswick Water Authority.

Computer-based storage and retrieval of water-quality data received from the Division's laboratories and from other federal and provincial agencies became operative during the year with some trial computer print-out of data towards the end of the year. Development of automated printing of data in keeping with a wide range of data-user requirements will continue as water studies are expanded throughout Canada.

Water Pollution Research Subdivision

The study of the treatment and control of base-metal mining wastes continued as the principal laboratory and field activity of the subdvision. A pilot-scale oxidation lagoon was constructed at the Brunswick Mining and Smelting Company property in New Brunswick and was operated with modest success during the late summer. Laboratory research indicated that the development of cultures of the bacillus Thiobacillus Ferro-Oxidans in a controlled oxidation system could oxidize the sulphur compounds which give rise to the acidity in the waste systems following oxidation. The system having been stabilized, residual metals could then be precipitated with lime.

Plans were being made for a pilot-scale water-and-waste-treatment-research laboratory at the Canada Centre for Inland Waters at Burlington. Construction of the laboratory building was rescheduled with completion now planned for early 1971, rather than 1972. With this rescheduling, preliminary plans for experimental water-and-waste-treatment units to be assembled in modular fashion were set out, and a consultant was retained to undertake detailed planning and design in 1970-71. When completed, the pilot plant will provide facilities for applied research not

only on conventional water-and-waste-treatment equipment and systems available today, but also in innovative systems and methods of treatment that arise from basic research in other laboratories.

Water Chemistry Subdivision

The Division continued to develop and expand analytical services at the Ottawa, Moncton, Calgary and Burlington laboratories. Priority was given to research on automation of methods and on the acquisition of automated analytical equipment to meet the growing work load without unduly increasing staff.

Facilities at Moncton and Calgary were expanded to accommodate the rapidly growing work loads in the eastern and western regions. The unit at Burlington continued to provide shore- and ship-based analytical services.

A significant increase in activity in the Calgary laboratory came with the start of the joint Canada-British Columbia study of the Okanagan Basin. The laboratory established a mobile laboratory in the valley and began on-site sampling and analysis. Work load at the Calgary laboratory also increased with the regular shipment of samples from the Okanagan for detailed analyses.

The emergence of mercury pollution as a widespread problem across Canada pointed up the need for a rapid, sensitive, and reliable method of detecting and measuring this element in water. The Methods and Properties section of the Ottawa laboratory moved rapidly to develop such a method and, by year-end, both the Ottawa and Calgary laboratories were equipped and were detecting mercury concentrations as low as 0.05 micrograms per litre. The Calgary laboratory thereafter provided analyses of samples collected in a federal-provincial program on prairie region waters, while the Ottawa laboratory undertook analyses of samples from water in northern Ontario and in the Great Lakes-St. Lawrence River-Ottawa River waters which were subsequently found to be contaminated.

The Division continued its participation in the activities of the American Society for Testing and Materials, and maintained close liaison with the Federal Water Pollution Control Administration in the United States to keep abreast of new analytical procedures and the development of water-quality criteria and standards. The Division provided the chairman and staff for an interdepartmental working group on the development of water-quality criteria for Canada. The group hopes to include representatives from all provinces, universities and industry.

Energy Development Sector

The Energy Development Sector continued to pursue its broad responsibilities of providing the advice, co-ordination and guidance necessary to ensure the effective development and use of energy resources for the optimum benefit of Canada. Although the experts of the Sector work in separate groups, according to energy source, policy considerations relating to an individual energy source or form include all aspects of the complex interrelationship between individual energy sources.

One of the more important programs initiated during the 1969-70 fiscal year was the development of an extensive inventory of energy resources which will include not only quantitative data but also all relevant qualitative aspects. The Sector, in conjunction with other departments and agencies, strives to develop an accurate energy-demand forecast at the regional, national and international levels. The projected energy supply-demand picture includes availability of accurate and up-to-date status reports on the energy industries of Canada.

The Sector's Resource Administration Division continued its ever increasing role in resource management in our offshore areas and in federally-owned lands. Canada's submerged continental margin is probably the largest in the world. Some 950,000 square miles of the total 1.5 million square miles of submerged shelf, which is as large as 40 per cent of Canada's entire land area, are under the administrative control of the Resource Administration Division. At the end of the 1969-70 fiscal year the Division had issued exploration permits for almost 400 million acres and was administering the work obligations and exploration programs associated with those permits.

The Resource Administration Division has also participated in a major way in discussions with provinces concerning lines of demarcation between federal and provincial jurisdiction over the offshore areas and the sharing of revenue which may result from oil and gas production.

ELECTRICAL ENERGY

The Electrical section of the Energy Development Sector is primarily concerned with the production and transmission of electrical energy throughout Canada, and seeks to co-ordinate and encourage the best use of available energy resources. The Electrical section therefore has a special interest in power-system planning, including the various forms and the siting of generating and transmission facilities. Requisite consideration is given to the economic and environmental factors associated with the development and production of electric power.

The section's interests also include auxiliary systems such as power-system control, communication, fuel supply and storage, and extend to research programs and facilities pertaining to power generation and transmission, and the development and improvement of electrical equipment and prime movers.

Atlantic Provinces Power Development Act

The Energy Group continued its advisory role in connection with the administration and review of the Atlantic Provinces Power Development Act by the Department of Regional Economic Expansion. Studies carried on during the year resulted in the decision to

terminate the financing of power projects in the Atlantic provinces under the provision of the Act. The Energy Development Sector is continuing its technical advisory role in connection with power-system planning and consideration of assistance to power projects that are of major significance to the power systems of the Atlantic provinces.

Upper Yukon Power Market Study

In co-operation with the province of British Columbia, the British Columbia Hydro and Power Authority, the Department of Indian Affairs and Northern Development, and the Alaska Power Administration, the Energy Development Sector continued its study of the market potential for power that could be developed by diverting a portion of the Upper Yukon River waters to a generating station located on tidewater in northern British Columbia or southeast Alaska. This study is being undertaken because of the favourable influence such a station would have on the resource development of northern areas lying within economical distance of such a source. The study will be completed in the fiscal year 1970-71 and will be the basis of a decision concerning the merits of further engineering and economic feasibility studies.

Quebec — New Brunswick Intertie

Following the decision to grant federal government support to the New Brunswick Electric Power Commission's high-capacity direct-current interconnection with the Quebec Hydro system, the Energy Development Sector has maintained an active contact with the Department of Industry Trade and Commerce concerning research and development of the equipment required for this project.

Hydro Quebec Research Institute

Following a review that confirmed the national interest in the establishment in Canada of a high-voltage and high-power electrical research laboratory, the federal government decided to give financial assistance to the Hydro Quebec Institute of Research, in the form of a long-term repayable loan of $17,500,000 and annual grants of $325,000 for ten years. The Energy Development Sector, in conjunction with other federal departments having an interest in electrical-power research, drew up an agreement between the federal government, the Quebec government and Hydro Quebec to govern the provision of financial assistance to the Institute of Research.

To ensure the most effective use of this research facility for the ultimate benefit of the Canadian electrical utilities and the supporting electrical-manufacturing industry, the agreement provides for guidance of the Institute's programs by a federal-provincial review board and a technical advisory committee. These bodies represent the governments of Canada and Quebec, Hydro Quebec and, through the Canadian Electrical Association and Canadian Electrical Manufacturing Association, other electrical utilities, and electrical-manufacturing industries of Canada.

By year end, a draft agreement acceptable to Quebec and Hydro Quebec had been developed and submitted for formal federal approval.

Columbia River Development

The Assistant Deputy Minister (Energy Development) continued his chairmanship of the International Columbia River Treaty Permanent Engineering Board, and the federal chairmanship of the B.C. — Canada Columbia River Advisory Committee.

The Permanent Engineering Board is responsible for ensuring that the objectives of the Columbia River Treaty are achieved. Under the Treaty three Canadian storage projects were to be constructed. Two of them, namely the Duncan and Arrow, have already been completed well ahead of schedule and, as a result, have produced additional benefits for both the U.S. and Canada. Construction of the Mica Dam, the largest of the three Canadian projects, is proceeding on schedule for completion in 1973.

The B.C. — Canada Columbia River Advisory Committee assists the federal-provincial committee of ministers in the implementation of the Treaty by Canada. The Minister of Energy, Mines and Resources is the federal chairman of the ministerial committee.

Atlantic Tidal Power Investigations

The Energy Development Sector continued its participation in the study by the Atlantic Tidal Power Programming Board of Bay of Fundy tidal power. The Board completed its three-year study during the year and submitted its report to the governments of Canada, New Brunswick and Nova Scotia. The Board concluded that while the development of tidal power in the Bay of Fundy is technically feasible, such power would not be economically competitive with alternative forms of generation.

The study reported in detail on the three most attractive tidal power sites in the Bay of Fundy and noted that further study of these sites might be warranted should there be a substantial reduction in interest charged on loans or should advances in construction or generating technology promise substantial cost reductions.

The Energy Development Sector is maintaining its interest in tidal power, and watches any developments that might have a bearing on the practicability of tidal power in Canada.

Nelson River Power Development

The Assistant Deputy Minister (Energy Development) serves as chairman of the Federal-Provincial Nelson River Review Committee established in accordance with the Canada-Manitoba agreement signed in 1967. The agreement pertains to development of the Hydro Electric Potential of the Nelson River.

The Energy Sector has maintained an active interest in the high-voltage DC transmission system that is being constructed by the government of Canada from the Kettle generating station on the Nelson River to a terminus near Winnipeg, and other aspects of the current program for development of the Nelson River. While the Review Committee's main duties will not begin until the transmission system becomes operative in 1971-72, the members held one meeting during the year to review construction progress and planning.

Electric Power in Canada

Responsibility for preparation and publication of the annual publication Electric Power in Canada and tabulation of electrical power developments and transmission lines, was transferred from the Inland Waters Branch to the Energy Development Sector.

During the year a brochure summarizing achievements in the development of electrical power in Canada in 1969 was prepared, and material was assembled for the 1969 issue of Electric Power in Canada and for revision of the map supplements.

OIL AND GAS

Canada's oil and gas companies engage in resource development in western Canada, the far north and offshore on continental shelf areas, production, cross-country transportation, chiefly by means of a vast network of pipelines, petroleum refining at several centres across the country; and wide-ranging marketing.

The Energy Development Sector assesses the regional, national and international implications of trends in each sector of the industry and makes policy recommendations based on the results of its research.

Several departments and agencies of the federal government are directly interested in various phases of oil and gas industry activity. Consequently, the co-ordinating policy role of the Department of Energy, Mines and Resources involves interdepartmental liaison and consultation to ensure that the full resources of government are brought to bear on the complex policy issues associated with the supply and use of oil and gas.

Canada — U.S. Oil Relations

Oil and gas relations with the United States continue to be of prime importance as that country constitutes Canada's sole export market. The United States now imports almost as much oil and gas as is delivered to domestic markets from western Canada fields.

Following a study of the U.S. oil industry in 1969 by a Presidential Task Force, a system of quotas against Canadian oil was initiated early in 1970 and the implications of this action are being assessed. This assessment is proceeding in terms of world supply, as both Canada and the U.S. also rely on oil from overseas sources in addition to continental supplies.

Northern and Offshore Oil Development

The trend towards the development of Canada's oil and gas resources in the far north and offshore is of increasing significance. Following the discovery of oil at Prudhoe Bay on the north coast of Alaska in 1968, exploration activity in Canada's northern frontier areas accelerated. The Task Force on Northern Oil Development was then established by the federal government to assess the supply-and-demand implications of Arctic oil and gas development and the various proposals for transportation to major marketing centres.

The Task Force, chaired by the Deputy Minister of the Department, has been giving particular attention to transportation assessments as made by oil companies that sponsored the two voyages of the supertanker *Manhattan* and by companies concerned with plans for oil and gas pipelines from Prudhoe Bay and the Mac-

kenzie Delta across Canada to U.S. markets. Ecology and pollution control are being given careful study as well as transportation and marketing economics.

Northern exploration and the drilling off Canada's east coast are contributing much specific information concerning Canada's oil and gas potential. Supply and demand assessments and forecasts must have regard to developments in these far northern and offshore regions, as they are believed to hold about 60 per cent of Canada's total oil and gas resources.

Future Oil and Gas Requirements

Energy requirements in Canada are doubling every 15 years, and oil and gas will continue for many years to meet about three-quarters of these requirements. Domestic oil production is now equal to total domestic demand. This balance has been reached through growth in exports to the level of imports into eastern Canada, an area beyond the economic reach of western Canada crude.

To maintain and improve this supply-demand relationship requires not only major exploration and marketing efforts by industry but appropriate resource-development, transportation, marketing, and taxation policies on the part of government. Policy studies are therefore concerned with supply and demand relationships and also with the structure and operation of the oil and gas industry within the framework of broad national objectives relating to such matters as economic growth, employment, ownership and control, and the reduction of regional disparity.

Environmental Management

The increasing concern regarding pollution and the need for adequate environmental management has introduced a new dimension into cost/benefit analyses of oil and gas projects. All activities of the oil and gas industry ranging from exploration, through production, transportation, refining, and marketing create some pollution hazards for land, sea or air. Feasibility studies, and the policy recommendations arising from them, are therefore having regard to the costs of pollution prevention and control.

This new requirement must now be costed, and increasing attention is being given to research to ensure the development of secure and economic environmental control procedures. Included in the work of the Energy Development Group on this subject is its participation in a government-industry committee concerned with pipeline technology in northern terrains where ecological control is vital because of the unstable nature of permafrost and muskeg areas.

International Interests

International trends in the oil and gas industry are followed through participation in such organizations as the Oil Committee of the Organization for Economic Co-operation and Development (O.E.C.D.) and the World Petroleum Congress. International affiliations afford a means of appraising the impact of world petroleum resource developments and price trends on supply and demand within Canada.

COAL

A strong resurgence is taking place in the coal industry of western Canada to meet the rapidly growing demands of the export and home markets. This recovery was promoted since its early stages by joint federal-industrial programs including subvention aid, technical advice and mine-improvement loans. During the year, a number of coal companies completed their current programs of expansion and modernization to supply these markets. Several other companies are in the development stage.

Also during the year, the Canadian National and Canadian Pacific Railways inaugurated unit-train systems for the more efficient transportation of coal, and new coal-loading facilities were completed at the Port of Vancouver. As a result of these developments in western Canada, Canadian coal production is expected to increase from the 1969 level of approximately 10½ million tons to about 40 million tons by 1975 and to 60 million tons by 1980.

During the year, the coal consumers of central Canada, particularly in Ontario, began to experience a shortage of coal supply because of production problems at mines in the United States. Consequently, the steel-making and electric-utility industries as well as smaller consumers have been materially affected. Moreover, the increasingly strict civic regulations against the use of high-sulphur fuels have aggravated this position of short supply. In consequence, the Ontario consumer is showing greater interest in western Canada coals. The low sulphur content of these western coals, together with improved efficiencies at the mine and on the Canadian railways, give promise of substantial sales in Ontario and a lessening of the dependency on imported coal.

With respect to the tight situation in supply and demand for coal, the Energy Development Sector is maintaining a close liaison with central Canada consumers as well as with the coal producers of western Canada and the United States.

Transfer of the Staff of the Dominion Coal Board to the Energy Development Group

Legislation was passed during the year for dissolution of the Dominion Coal Board and for the transfer of its responsibilities to the Department of Energy, Mines and Resources. The transition of responsibilities has proceeded smoothly between the staff of the Dominion Coal Board and the Energy Development Sector, with the Board staff becoming the Coal Advisory section of the Sector.

Departmental Commitee on Coal

During the year, a departmental advisory committee on coal was established to co-ordinate and make best use of all existing knowledge and facilities within the Department. To make it even more effective, it is proposed to expand it to interdepartmental level by including representation from other interested departments. The first task of this committee was a reassessment of the measured coal reserves of western Canada; a report will be completed early in 1970-71. Additional assignments will include the determination of the quality of these coal reserves and their relative mineability, together with an investigation into existing and potential markets.

It is also proposed to make this committee a useful point of contact with the coal industry, including the consumers and transporters of coal. Toward this end, the industry is being encouraged to establish a fully representative industrial association to expedite a systematic exchange of views with Ottawa.

Coal Industry in the Maritimes

In the Maritime provinces, the coal industry continued to be phased down in accordance with joint federal-provincial programs for bringing coal production more in line with available markets and for introducing other industries.

The Canadian Conference on Coal

As part of its responsibility for co-ordinating energy-related matters, the Sector organizes and administers the annual Canadian Conference on Coal in co-ordination with the Coal Operators' Association of Canada and the Canadian Institute of Mining and Metallurgy. The Conference is a public forum for the exchange of ideas and the dissemination of knowledge related to coal resources and their orderly utilization.

The Phasing-Out of Coal Subventions

As a result of the improved economic situation in western Canada and of the alternative programs instituted for Nova Scotia and New Brunswick, federal subventions have been phased out and will be discontinued in 1970-71. In future, federal support will consist of research and development aimed at promoting long-term stability of the industry. This will include investigations into the problems of coal production, processing, transportation and utilization.

URANIUM AND NUCLEAR ENERGY

There are many activities associated with uranium and nuclear energy that require immediate and extensive attention by the federal government. The strategic importance of uranium, Canada's large uranium reserves, the economic significance of uranium domestically and as an export commodity and changing international developments, all require sound and flexible national policies and guidelines.

There are many federal departments and agencies that participate in a variety of studies and policy formulations concerning uranium and nuclear energy. The staff of the Energy Development Sector participates in the development and recommendation of policy on nuclear energy, uranium and associated matters. The Sector co-ordinated and conducted studies which led to announcement of a new export policy as outlined by the government on June 9, 1969. While maintaining Canada's policy with respect to nuclear safeguards, the policy reflects the increased world demand for uranium and requires examination and approval of export contracts on the basis of such factors as reserves, domestic needs, rate of exploration and price.

Foreign Ownership in the Canadian Uranium Industry

Because of factors mentioned above, the question of foreign ownership of uranium mines in Canada is an important element in the overall considerations of foreign ownership of our industries.

Subsequent to the Prime Minister's statement of March 2, 1970, on the government's position with regard to ownership in the Canadian uranium industry and the Honourable J. J. Greene's statement of March 19, 1970, outlining the criteria governing the proposed limitation of foreign ownership of uranium-producing enterprises in Canada, the Department was given the task of co-ordinating the preparation of regulatory measures required to implement this policy.

RESOURCE ADMINISTRATION DIVISION

The Resource Administration Division administers and manages the federal interests in mineral resources off Canada's east and west coasts and in Hudson Bay and Hudson Strait. The primary aim is to provide a uniform system of resource management that will, in a manner consistent with the public interest, encourage and maintain continuing and orderly investment in offshore mineral resource development and ensure that reserves discovered are as low in cost as possible. The Division also handles those federally-owned mineral rights in the provinces that become available for development.

In addition to the foregoing responsibilities, the Division develops and provides policy recommendations and advice in regard to matters related to the offshore; provides representation and expertise with respect to interdepartmental, federal-provincial and international offshore matters; provides co-ordination and liaison among numerous government and industrial agencies concerned with utilization of offshore areas; and provides expertise and advice to other governments and agencies concerning a wide variety of mineral-resource and related matters.

Offshore Mineral Resource Management

The total area of Canada's submerged continental margin is estimated to be in excess of 1.5 million square miles, about 40 per cent as large again as the total land area of Canada. Of this over 600,000 square miles lie off the east coast; 400,000 square miles lie in Hudson Bay and Hudson Strait; 50,000 square miles lie off the west coast; and some 500,000 square miles are in the high Arctic, in the Beaufort Sea and in the region of the Arctic Archipelago.

Preliminary investigations indicate that much of Canada's submerged continental margin is prospective for oil and gas. The Canadian Petroleum Association has recently estimated that the petroleum potential of Canada's east-coast shelf alone, including only areas to a water depth of 200 metres, amounts to some 25 billion barrels of oil and 150 trillion cubic feet of gas. Much lies beyond this; over 50 per cent of Canada's east-coast continental margin has water depths exceeding 200 metres. The potential for mineral resources other than oil and gas is also promising, although at present the mining industry lags considerably behind the petroleum industry in the offshore field.

Canada Oil and Gas Permits cover well over half of Canada's submerged continental margin. These offshore permits are issued and administered under the Canada Oil and Gas Regulations, promulgated pursuant to the Public Lands Grant Act of 1952. The Act gives statutory authority with respect to the offshore. Authority for dealing with offshore operational matters is also provided to a considerable extent by these regulations.

With the recent upsurge in offshore exploratory activity, particularly drilling, there is an urgent need for new and more comprehensive statutory authority to govern operational, production and conservation matters. This legislation would enable supervising authorities to continue evolving regulatory requirements and supervisory controls to keep pace with accelerating offshore activity and technology. In particular, it would enable the federal government to handle the new and complex situation that will arise upon the advent of commercial production.

A new bill to accomplish this with respect to oil and gas, Bill S-5, has been passed by the Senate and, at the end of this fiscal year, was before the House. The bill is designed to amend the Oil and Gas Production and Conservation Act, which became law last June, so that it will apply not only to the Canada Lands of the Yukon and Northwest Territories, but also to Canada Lands in the areas off Canada's sea-coasts. The amended Act will provide for more comprehensive statutory control over all offshore oil and gas activities, the safety of personnel and the prevention of waste and pollution. The Act's broad authority includes regulation of the exploration and drilling for, and the production, conservation, storage, transportation (pipelines), distribution, measurement, processing and other handling of offshore oil and gas.

In response to the upsurge in drilling activity off Canada's east coast, and in order to provide the

regulatory control embodied in the Act, the Division during the year began construction of a $126,000 regional office building on the site of the Bedford Institute in Dartmouth, Nova Scotia. This building will provide office space for a regional conservation engineer and his staff, who will be responsible for on-the-spot supervision and regulation of east-coast offshore drilling. The building will also include laboratory facilities for the processing, storage, curating, research and examination of cores and cuttings from east-coast offshore wells. Among the major considerations are the prevention of pollution, the safety of personnel and the conservation of mineral resources as well as the living resources of the sea.

At the end of the fiscal year, the Division was recruiting engineering and support personnel to staff the regional office, and sought to design and enforce comprehensive and up-to-date regulations for the offshore under the Oil and Gas Production and Conservation Act as amended.

Offshore Activity

During 1969, $22 million were spent by oil companies on offshore Canada Oil and Gas Permits administered by the Division, an increase of $4 million over that spent in the previous year. This brought the cumulative expenditures by companies engaged in oil and gas exploration in Canada's offshore areas to more than $80 million. During the year, the Division approved 38 separate offshore exploration programs and ensured that they were carried out in accordance with federal requirements.

Highlights of 1969 included:

1) completion of Shell Canada's exploratory drilling program off the west coast, with four additional exploratory wells drilled and abandoned for a total of 14 wells drilled during a two-year effort;

2) commencement of Shell Canada's exploratory drilling program on the Scotian Shelf off the east coast, with the abandonment of the first well with a significant show of gas, and the commencement of a second well; the semi-submersible rig used was to be joined by a second vessel in 1970 after construction in Halifax was completed;

3) drilling of the first well in Hudson Bay, about 125 miles offshore, and the drilling of a well farther to the northeast in the Hudson Strait region, on Akpatok Island in Ungava Bay;

4) announcement that a drilling program would be carried out in the summer of 1970 in the Gulf of St. Lawrence off Prince Edward Island.

Canada Oil and Gas Permits

A total of 371 Canada Oil and Gas Permits covering 23.2 million acres were issued during the fiscal year 1969-70 in offshore areas administered by the Division, as follows:

East Coast	— 247 permits	— 15,607,407 acres
West Coast	— Nil	— Nil
Hudson Bay-Hudson Strait	— 124 permits	— 7,563,822 acres

This brought the number of offshore Canada Oil and Gas Permits (except in the waters of the high Arctic) as of March 31, 1970, to 5,500 covering 389.3 million acres as follows:

East Coast	— 3,417 permits	— 259,021,252 acres
West Coast	— 251 permits	— 15,600,154 acres
Hudson Bay-Hudson Strait	— 1,832 permits	— 114,688,492 acres

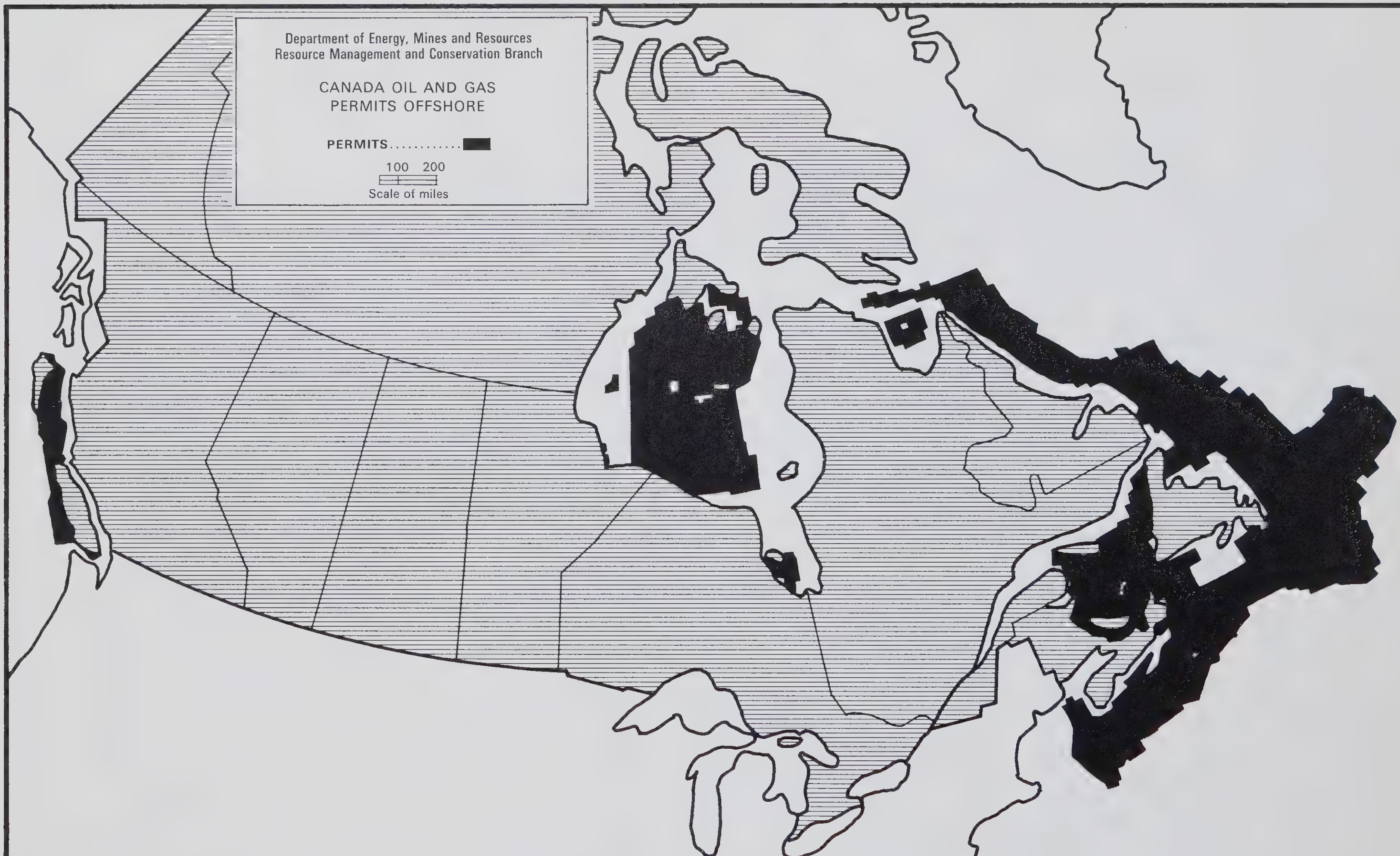
The total revenues received during the fiscal year 1969-70 from offshore permits, including permit fees, transfer fees, forfeitures, exploratory licences and maps amounted to $204,915.76, most of which was derived from permit fees.

Mineral Claims

Offshore mineral claims are issued for mineral rights other than oil and gas rights under the Canada Mining Regulations. A total of 165 offshore mineral claims were recorded during the past year in the Hudson Strait region. This brought the total number of mineral claims to 483, distributed as follows: east coast, 143; west coast, 108; Hudson Bay, 232. Total revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1969-70 amounted to $1,407.62.

Federally-Owned Mineral Rights in the Provinces

During the fiscal year 1969-70 nine oil and gas leases were issued. Four of these were in Alberta, three in Saskatchewan and two in Manitoba, bringing the total number of federal oil and gas leases in the provinces to 231. Of these 103 were issued in Alberta, 80 in Saskatchewan, 44 in Manitoba and four in Ontario.



The Resource Management and Conservation Branch is responsible for the management of the federal interests in the mineral resources of all Canada's offshore areas with the exception of the high Arctic. This responsibility includes the exercise of comprehensive statutory control over all exploratory and development work with such matters as, the prevention of pollution, the prevention of waste of resources, and the safety of personnel, being of primary importance.

To date, interest in offshore mineral resources has been confined primarily to the search for oil and gas, and in 1970 more than 130 companies held a total of 410 million acres under exploratory permit. The oil and gas industry has spent a total of $120 million, on the drilling of 46 wells and on numerous geophysical surveys, to explore this acreage. Offshore exploration activities are continuing to increase rapidly with expenditure of $55 million anticipated in 1971-1972.

In addition, two leases for minerals other than oil and gas are held in Ontario. On March 31, 1970, 68 oil and/or gas leases were productive as follows: 36 in Alberta, 22 in Saskatchewan, nine in Manitoba and one in Ontario.

The total revenues received during the fiscal year 1969-70 from oil and gas leases, including royalties, lease-sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $280,754.42, most of which was derived from royalties.

Administration

The Administration program comprises the central Ministry supporting functions (Executive Offices, Finance and Administration, and Personnel and Organization) and the specialized services (Public Relations and Information Services, Computer Science Centre and Technical Field Support Services), maintained centrally to support other elements of the department.

A Monitoring Committee under the chairmanship of the senior assistant deputy minister was formed to stimulate and guide the implementation of the recommendations contained in the report of the Bureau of Management Consulting Services, as accepted by the department. Considerable progress was made, but another year is required to achieve the desired results.

A semi-official committee comprising senior branch administrative officers was formed to improve communications and understanding between headquarters and the operating units.

FINANCE AND ADMINISTRATION

The organization to meet the recommendations of the report of BMCS and the needs of the department was prepared and approved by requisite authority. The report recommended a shift in emphasis to that of planning and policy formulating at the departmental level and to the publishing of guidelines and procedures to enhance uniformity; this enables line officers to handle day-to-day administrative responsibilities to the greatest possible extent. It is anticipated that the reorganization will be completed during the next fiscal year.

The accounting system for Technical Field Support Services was revised and implemented. A new field equipment list was issued for the use of field officers.

The Departmental Secretariat co-ordinates and edits parliamentary returns, applies claims regulations to motor vehicle accidents and claims against the Crown, administers licences for patents for departmental employees under the Inventions Act, handles submissions to Treasury Board and memoranda to Cabinet, and edits and publishes procedural manuals. Four procedural manuals were issued during the year and five additional ones reached the draft and final discussion stage.

As a result of certain amendments to the Financial Administration Act, the Department assumed the responsibility for the pre-audit of accounts and claims, the preparation of financial accounting reports and other related services formerly provided by the Department of Supply and Services. The staff formerly employed in these areas of responsibility was transferred to the department on September 1, 1969. Certain procedural changes were necessary and these were instituted without any interruption in the service to the branches.

A 50 per cent increase in leases was noted; half were short-term leases, mainly for the water sector. There

was a constant demand for increased space, alterations and surveys, leading to either new leased accommodation or a new building.

In capital construction, the major completions involved the extension to the core laboratories in Calgary and the completion of the research plant at the Bedford Institute. A number of specialized installations in the Observatories Branch were completed, and design and construction work was carried out on the diesel test lab and rifle range at Corkstown Road.

PERSONNEL AND ORGANIZATION

At peak employment, the department had 6118 employees comprising executive, 29; scientific and professional, 1317; administrative and foreign service, 295; technical, 2431; administrative support, 1011, and operational, 1035.

Complete appraisal systems were developed and implemented for the Economics and Administrative Services groups. A Career Development Program for administrative officers was initiated.

Phase 1 of the Management Grid Development Program was provided to 109 officers from various branches. A supervisory development course was prepared and implemented. Educational leave was provided to 57 employees, ranging from zero to full pay, in work fields where it was difficult to recruit qualified staff. Some 170 departmental employees were enrolled in French language training.

The Cabinet freeze on continuing strength as of 31 July, 1969, required submissions for relief and review and approval by senior management of all staffing actions, on the basis of departmental priorities.

Recruitment was relatively successful for the specialized occupational groups required in the water and energy sectors. Some 900 students were employed during the summer for office, laboratory or field operations.

Most of the 42 collective agreements applicable to departmental employees were implemented during this period. Advice and assistance was provided to line management and staff officers on the implementation and interpretation of collective agreements and the resolution of grievances. Assistance was provided to Treasury Board on collective bargaining, especially where the department had a significant number of employees in the occupational group concerned.

A new disciplinary policy for ships' crews was developed and implemented. The departmental grievance procedure was revised.

The Deputy Minister introduced an official safety program. Departmental policy was established and a safety manual prepared and distributed. A departmental safety co-ordinator was appointed at headquarters as well as safety officers in most branches.

The work load involved in the classification of new positions and the reclassification of existing positions was heavy, partly because of a number or organizational changes. Training in job description writing and the classification of positions was provided to line management in most of the branches.

The conversion of positions from the old classes into the new occupational categories, groups and levels continued. The work was given high priority as it was required for collective bargaining. There was a significant backlog, mainly in the Scientific and Professional category and in the Engineering and Scientific Support group. The number of classification grievances was high.

The changeover from a punched card to a computer data system continued. The department assisted the Public Service Commission in developing a scientific vocabulary for data stream, especially in disciplines where the Department employed a significant number of professionals.

Advice and assistance was provided to line management concerning employees with alcoholic, health and work problems. Counselling was provided, as necessary, to the employees concerned.

COMPUTER SCIENCE CENTRE

The Computer Science Centre commenced the implementation of the recommendations of the Bureau of Management Consultants, as accepted by the department, to reorganize the Centre and to acquire a large-scale centralized computing facility. Most of the important staffing actions have been completed or are in the process of being completed.

Work was also commenced on the acquisition of new computing facilities. Following a period of intensive analysis of the present and projected work loads of the department, specifications of a computing facility capable of handling the required work load, were prepared and incorporated into an invitation to tender, which was issued April 15, 1970.

The Centre made a start on the development of a personnel data system and a system designed to assist in controlling an inventory of the equipment issued to the departmental field parties.

Of particular interest was the development of the computerized portion of a Water Quality Data System in co-operation with the Inland Waters Branch. The system provides the capability of editing, storing, manipulating and displaying information that describes the results of analyses of water samples from sampling stations across Canada.

PUBLIC RELATIONS AND INFORMATION SERVICES

The Public Relations and Information Services Branch provides support services to management that contribute to the attainment of the department's goals and the objectives of its programs.

The Branch comprises the Interpretive Writing, Media Relations, Graphic Arts, and Publishing Sections.

During the year, the Branch stationed a regional information officer at the Canada Centre for Inland Waters at Burlington, Ontario, and obtained a position for a similar officer at the Bedford Institute in Dartmouth, N.S.

The publicity highlight of the year was HUDSON 70, an 11-month, 41,000-mile oceanographic expedition around South and North America. The CSS *Hudson* left Dartmouth, N.S. in November 1969. Some 125 scientists from government laboratories and universities in Canada, United States and South America participated in the expedition, studying the Atlantic, Antarctic, Pacific and Arctic oceans.

Press kits on the expedition were prepared in English, French, Portugese and Spanish. Press conferences were held at Dartmouth, Nova Scotia, on the ship's departure, at Vancouver in June 1970, and at the termination of the expedition in Dartmouth in October 1970. With the co-operation of the Department of External Affairs, successful press conferences were held at the ship's ports of call in Rio de Janeiro, Buenos Aires, Punta Arenas, and Santiago. The expedition received extensive publicity in Canada and in the various ports of call in South America.

"Everybody's War", a Branch brochure on water pollution, proved so popular that a total of 75,000 English copies and 25,000 French copies had to be produced to meet the demand.

A start was made on the production of a series of six water pamphlets in response to requests for information on water pollution and water management.

Media Relations produced and distributed 81 press releases and 23 Minister's speeches in both official languages.

The Graphic Arts Section created and produced the designs for the various Branch publications and exhibits. Photographic assignments included press and publicity coverage of ministerial conferences, field projects and interdepartmental activities and still and movie photography of scientific projects. New earth science films were purchased and deposited in the EMR section of the National Science Film Library.

Fifty per cent of editorial man-hours was devoted to 12 large manuscripts during the year, of which the following were published: Transactions of the International Peat Congress, Mining and Groundwater Geophysics, Men and Meridians, Vol. 3, Proceedings of 5th International Conference on NDT, Combustion Handbook on Canadian Fuels, Vol. 1, Canadian Minerals Yearbook 1967 (French), Canadian Minerals Yearbook 1968 (English).

The following were edited but not brought to the publishing stage: translated parts of Geology and Economic Minerals of Canada (French), Geology and Economic Minerals of Canada, Prospecting in Canada, Canadian Minerals Yearbook 1968 (French), Canadian Minerals Yearbook 1969 (English), Men and Meridians, Vol. 1 (French).

Some 14,500 printed pages in all were edited, totalling 94 books of which 79 were published and 15 were in the process of editing. All books originated in branches of the department.

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
OTTAWA, CANADA

annual report 1970-71

Hon. Donald S. Macdonald, Minister

Department of
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Mica dam, Columbia River development project, British Columbia.

New Directions

As a result of important and far-reaching policy decisions, the Department of Energy, Mines and Resources has been charged by the Government of Canada with increased responsibilities in the safeguarding and development of the nation's energy and minerals resources. In order to sharpen and to emphasize this new thrust in the Department's activities, and to free it for its vital new tasks, it was relieved of responsibilities for water research and astronomy, which were transferred to other agencies.

Critical issues facing Canada's energy and mineral economy include the implications of tax reform, the need to expand foreign markets while encouraging further processing at home, environmental problems caused by

mineral and energy development, Canadian control and ownership of energy industries, U.S. import quotas on Canadian oil, and the maintenance of a viable uranium industry.

The new Department of Energy, Mines and Resources that took shape during the report period of 1970-71 viewed its tasks and responsibilities not only in the light of technical and economic factors, but also social factors. What can our geological resources, known and unknown, contribute to Canadians, and at what cost? How much industrial growth does the nation want, how much foreign ownership is consistent with the welfare of the Canadian people, and what will the impact be on the environment and the standard of living? Will a certain policy reduce or increase regional economic disparity? These are some of the questions faced by EMR policy advisers, in common with all other departments.

The Department conducts its activities under three main heads — energy, which covers policy on electric power, petroleum, coal, uranium; mineral development, which covers policy recommendations on all mineral commodities; and science and technology, which covers surveys and research in such fields as mapping, geology, metallurgy, mining technology, geophysics, and provides the basic data on which policies are necessarily based.

ENERGY DEVELOPMENT

The Energy Development Sector of EMR seeks to influence the development and use of Canada's energy resources in such a way that they will produce the maximum benefits for Canadians of the present as well as future generations. To this end, its experts collect and analyse data on all activities and supply-demand conditions in the field of petroleum, natural gas, coal, uranium, and electrical power, and they make policy recommendations to the federal government based on these analyses and on projections into the future. They also control and manage oil and gas exploration in offshore regions, including operational, conservation, safety and anti-pollution measures.

In the field of electric power, a highlight of the year was the signing of an agreement between Canada, Quebec, and Hydro Quebec providing for federal financial assistance to the Hydro Quebec Research Institute. Under the agreement, Canada will lend Hydro Quebec $17.5 million, repayable over 25 years, and make ten annual grants of $325,000 each. The agreement stipulates that the institute will serve the entire Canadian electrical industry, especially with research in high-voltage and high-power transmission. A review board and a technical advisory committee, both with national representation, were set up to ensure that the overall objectives of the institute are achieved.

Emphasis in oil and gas exploration is now placed on the frontier areas of the far north and the offshore areas on the east coast. In December 1968, the government established the Task Force on Northern Oil Development for interdepartmental advice and co-ordination. Under the chairmanship of the Deputy Minister of EMR the task force has been conducting appraisals of pipeline engineering, environmental control, marine transportation, oil and gas marketing, and the economic impact of northern oil development and pipeline activity. Recommendations concerning policy for northern pipelines were published in August 1970 to provide industry with a set of guidelines for planning the construction and operation of pipelines from Arctic regions to southern markets.

The National Oil Policy, under which that part of Canada lying west of the Ottawa Valley is reserved for domestic oil, continued to be reviewed in the face of economic pressure from foreign-produced oil.

During the period 1963-70, the federal government spent $101 million on a program for stockpiling uranium oxide, of which it accumulated 19 million pounds. A further $39 million is to be spent in the years 1971-74, for 6.3 million pounds from a joint program with Denison Mines Limited, the largest Canadian supplier of uranium. A new Crown corporation, Uranium Canada Limited, was incorporated in 1971 to act on the government's behalf in the acquisition and later disposal of the stockpiles. These actions will help to ensure the existence of a viable Canadian uranium industry during the rapid world-wide expansion of nuclear-reactor use predicted for this decade.

The question of foreign ownership of uranium mines in Canada is an important part of the question of foreign ownership of Canadian resources. In March 1970 the federal government announced a policy, according to which any sales of foreign holdings in any uranium-producing company must be made to Canadian residents, until the total foreign ownership is reduced to 33 per cent. Also, no foreign investor, or group of associated foreign investors, will be allowed to retain more than a ten-per-cent ownership in a uranium property.

The Energy Development Sector contains the Resource Management and Conservation Branch, which provides recommendations and advice on offshore mineral resource

policies and programs, manages and administers federal interests in mineral resources off the east and west coasts and in the Hudson Bay and Hudson Straits regions, including supervision and control over exploration and development activities, and administers federally-owned mineral rights within the provinces. During the fiscal year 1970-71, a new bill amending the Oil and Gas Production Act was passed to extend the authority of the Act to operation, production and conservation matters of the offshore. The Act sets out conditions designed to protect the marine environment and to ensure the orderly and efficient development of petroleum resources.

During 1970, oil companies spent $37 million in the evaluation of offshore Canada Oil and Gas Permits administered by the Branch, an increase of $15 million over 1969. In that same year, the Branch approved 80 separate offshore exploration projects. At March 31, 1971, the Branch had issued 5,909 Canada Oil and Gas Permits, covering 414 million acres of the offshore.

MINERAL DEVELOPMENT

The Sector is concerned with mineral affairs from a resource management viewpoint. In structure, the Sector is composed of the Mineral Resources Branch and the Explosives Division.

The Mineral Resources Branch is concerned with resource economics. On resource problems connected with mineral development, it provides advice and analyses on both the short and long-range outlook for minerals in the Canadian economy including markets and supply-demand relationships.

This Branch is also concerned with encouraging and extending the pattern of development in Canada. In areas where minerals are a suitable vehicle for development, the Branch participates with other federal and provincial departments in studies and plans intended to further the development of mines, smelters or processing facilities and related transportation needs. Examples include: the Northwest Canada Resource Transportation Study, a mineral development program in New Brunswick, and an evaluation of the economic mineral potential of Manitoba.

Among the functions of the Mineral Resources Branch is administration of the Emergency Gold Mining Assistance Act (EGMAA), first passed in 1948 to extend the operating life of gold mines in economic difficulties and thereby to save the communities that had grown up around the mines. Amendments to the Act, which received Royal Assent in February 1971, extended the Act to June 30, 1973, and placed certain obligations on the gold mines to ease the effect of possible closure on employees.

The Explosives Division administers the federal Explosives Act which covers factories that produce explosives and also transportation, storage and importation. Its work is designed to safeguard the public and promote safety.

SCIENCE AND TECHNOLOGY

This Sector is the Department's largest in terms of staff and facilities. During the period covered by this report, it embraced the Surveys and Mapping Branch, the Geological Survey of Canada, the Mines Branch, the Earth Physics Branch, and the Polar Continental Shelf Project. In 1971, two more autonomous units were formed within the Sector — the Canada Centre for Remote Sensing and the Atlantic Geoscience Centre.

Two projects of the Surveys and Mapping Branch, because of their vast scope and impact, caught the attention of the general public. These were the air photographs of the Prairies which were taken during the first two weeks in August in support of the Lower Inventories for Tomorrow program, and the start of the detailed mapping of the Mackenzie River valley, the so-called pipeline corridor. The air photography mentioned above was carried out to monitor adherence by farmers to the stipulations of the LIFT operation. Under the terms of this federal measure, which was announced in February 1970, farmers who reduced wheat acreage and increased summer fallow by a corresponding amount received federal compensation payments of six dollars per acre. The mapping of the Mackenzie Valley was required in order to assess the potential impact of pipeline and other industrial installations in that important area and to provide information for those interested in undertaking such development. Altogether, 120 maps were compiled at a scale of 1:50,000.

One of the top priorities of the Geological Survey of Canada is the completion of the national geological reconnaissance of Canada at scales of one inch to four miles and one inch to eight miles. It is estimated that at the present rate this task will be completed about 1976. Completion

Ornamental monument marking the intersection of the Manitoba, Saskatchewan and international boundaries.

of the reconnaissance phase will permit expansion of regional multidisciplinary analyses by integrated teams that is needed for objective evaluation of our national endowment of energy and minerals.

A new section was formed as a focus for the Geological Survey's expanding geological appraisals of oil and gas potential of the Atlantic coastal shelf and eastern Canada. The section is located in the Atlantic Geoscience Centre. Also important for petroleum exploration in that region was the Earth Science Symposium on Offshore Eastern Canada which took place in Ottawa during February 1971. The symposium was attended by 373 persons, of whom 215 represented private companies.

A new Division of Geological Information Processing was formed in April 1970, whose prime role is the transfer of scientific results to potential users with minimum delay. In addition to processing maps and reports for publication, introduction of a new system of prompt information release by open file was very well received.

In order to provide essential information on surficial materials and terrain sensitivity to construction, along possible routes of the Mackenzie Valley pipeline and transportation corridor, field mapping was started and preparations were made for a greatly expanded program by the Geological Survey.

A hydraulic flume of advanced design with an 18-metre channel was installed by the Terrain Sciences Division for purposes of studying factors controlling sedimentation, erosion, stream flow and flooding. Results will be useful in engineering design, mineral resource location, maintenance of channels, and erosion control.

For the Mines Branch, 1970-71 marked the completion of the relocation of its fuel-research facilities to new, improved quarters on the western outskirts of Ottawa. The fuels-research specialists achieved significant advances in their fight to reduce air pollution from combustion, both in removing pollutants from fuels and in reducing the harm from combustion gases by dispersal into the atmosphere.

The efforts to develop a satisfactory thermal method for destroying liquid DDT culminated in the construction of a $150,000 incinerator by the Defence Research Board at Suffield, Alberta, based on a design developed in the Branch's Canadian Combustion Research Laboratory.

The Branch also succeeded in devising a method of "finger-printing" oil from oil-spills at sea, thus making it possible to track down the offending carrier.

Precise knowledge of ore composition in slurries is of great value in controlling ore dressing. The Mines Branch has

Mines Branch Research Centres complex at Bells Corners, outside Ottawa.

made significant contributions in the development of ore-slurry analysis by the use of radioisotopes, which are compact and portable, directly on stream to give an instant read-out of slurry composition. It is expected that this approach to slurry analysis will find many uses in the mining industry.

The discovery and exploitation of large deposits of strontium sulphate in Cape Breton Island prompted Mines Branch experts to look into better means of extracting and using this rare element. A new concentration process was developed, using flotation. As to industrial application, work is proceeding on the use of strontium in ferrites, devices widely used in the manufacture of television sets and computers. Strontium research at the Mines Branch, both in the fields of extraction and industrial application, is a good example of the aid a government laboratory can give to an emerging industry and the economy of a region that is especially in need of such diversification.

One of the notable achievements of the scientists of the Earth Physics Branch occurred in the field of crater research. There are many identifiable ancient craters in the Canadian Shield, and controversy continues to rage whether these are of volcanic or meteorite origin. The discovery of the silica mineral coesite — the first such find in Canada — in the Lake Wanapitei crater near Sudbury has convinced the scientists that the crater was caused by the impact of a meteorite.

The Branch's geomagnetists studied the magnetization of rocks from Vancouver Island and came to the preliminary conclusion that 200 million years ago the island was not part of the North American continent but was located thousands of miles away in the central Pacific.

In the field of seismology, an important event was the publication by the Branch of a detailed evaluation of present world-wide seismic capabilities, entitled *Seismological Detection and Identification of Underground Nuclear Explosions.* The volume was distributed by the Canadian government at the 26th General Assembly of the United Nations.

The small staff of the Polar Continental Shelf Project continued to provide logistic support to various departmental and non-departmental scientific activities in the high Arctic. Noteworthy among these was preparation for the Arctic Ice Dynamics Joint Experiment (AIDJEX), which seeks to elucidate the interaction between fields of motion in the atmosphere, the pack ice, and the liquid ocean. Such an understanding is basic to forecasting ice conditions and other weather factors. The main program is scheduled to take place in 1973-74.

The Atlantic Geoscience Centre was formed around certain units and functions formerly part of the Atlantic Oceanographic Laboratory at Dartmouth, N.S., which

was transferred to the Department of the Environment. The research of the new centre is concerned chiefly with marine geology and geophysics. The most notable project of the 1970-71 fiscal year was the geophysical component of the HUDSON 70 project — the circumnavigation of the Americas by the Canadian Scientific Ship *Hudson* from November 1969 to October 1970. Scientists carried out extensive bottom sampling while the ship traversed the Beaufort Sea and did a seismic-refraction survey of Baffin Bay.

Closer to home, off the coast of Nova Scotia, the grounding and sinking of the Liberian tanker *Arrow* in February 1970 had released 2.5 million gallons of bunker oil into the sea, polluting Chedabucto Bay and its shore. The Atlantic Geoscience Centre used the opportunity to study the various self-cleaning processes of the ocean environment.

Canadian scientists and particularly the geophysicists of EMR have for some time been following the advances in remote sensing with keen interest. Remote sensing, as understood by the scientific community, is the scanning of the earth's surface from a distance with various types of instruments. Thus far, pre-eminence among sensors has belonged to the photographic and television cameras, notably in the infrared band of the light spectrum. Cameras and other instruments may be carried by high-flying aircraft, satellites, balloons or rockets.

In July 1969, the Cabinet Committee on Science Policy and Technology instructed EMR to establish an Interdepartmental Committee on Resource Satellites and Remote Airborne Sensing supported by a Program Planning Office (PPO), which undertook various preliminary studies on the role to be played by Canadian science, and particularly government science, in this new and exciting field of observing our environment and cataloguing its resources.

In August 1970, the government awarded $201,360 in contracts to eleven Canadian companies and universities for the development of remote-sensing devices.

In February 1971, Treasury Board approved the establishment of an organization in EMR to be known as the Canada Centre for Remote Sensing, and in May of that year, EMR signed an agreement with the U.S. National Aeronautics and Space Administration (NASA) according to which the Canada Centre for Remote Sensing would be able to receive imagery from a remote-sensing satellite (termed Earth Resources Technology Satellite) scheduled to be launched by NASA in 1972.

Energy Development Sector

ELECTRICAL ENERGY

The Energy Development Sector is primarily concerned with federal programs and policies for the production and transmission of electrical energy throughout Canada, and seeks to co-ordinate and encourage the best use of available energy resources. The Sector therefore has a special interest in power-system planning, including the various forms and the siting of generating and transmission facilities. Consideration is given to the economic and environmental factors associated with the development and production of electric power.

The interests of the Sector include support systems such as power-system control; communication; supply, transport and storage of fuel; research programs and facilities pertaining to power generation and transmission; and the development and improvement of electrical equipment and prime movers.

Power Development in the Atlantic Provinces

The Energy Development Sector continued its technical advisory role in connection with studies by the Department of Regional Economic Expansion concerning assistance to power projects that would be of major significance to the power systems of the Atlantic provinces. Discussions were continued with officials of the Department of Regional Economic Expansion and the maritime utilities, and the Sector sponsored a special study on the organization and operation of power pools.

The Sector continued the federal interest in tidal power arising out of the studies by the Atlantic Tidal Power Programming Board completed in the preceding year. Discussions were held with representatives of New Brunswick and Nova Scotia concerning developments that bear on the economic feasibility of Bay of Fundy tidal power, and at year end, discussions were taking place concerning a formal review of the ATPP Board report in the light of current circumstances.

Upper Yukon Power Market Study

A report *Upper Yukon Power Market Potential* was completed and issued by the Sector. This report summarizes the conclusions of the study undertaken in co-operation with the province of British Columbia, the British Columbia Hydro and Power Authority, the Department of Indian Affairs and Northern Development, and the Alaska Power Administration, on the market potential for power that could be developed by diverting a portion of the Upper Yukon River waters to a generating station located on tidewater in northern British Columbia or southeast Alaska. This study found that while the market potential for such power is not unfavorable it is evident that the combined potential markets of northern B.C., Yukon and Alaska would not be adequate to support the project; hence more remote markets such as central and southern B.C., and possibly the Pacific Northwest area of the United States, would have to be supplied to create a

viable project. The report identifies a number of additional studies required to confirm the various cost factors. It also recognizes that further consideration of this project would have to be accompanied by an intensive study of how the ecology and environment of significant areas of the Yukon and northern B.C. would be affected by partial diversion of the headwaters of the Yukon and the creation of storage on the Yukon and the tributary lakes and river systems.

Hydro Québec Research Institute

The Energy Development Sector was responsible for co-ordinating the work of several federal departments pertaining to federal assistance to electrical research, with particular reference to the electrical research institute being developed by Hydro Québec.

An agreement between Canada, Québec and Hydro Québec providing for federal financial assistance to the Hydro Québec Research Institute was formally executed by the Minister of Energy, Mines and Resources, the Minister of Natural Resources of Québec and the President of Hydro Québec, at a ceremony in Montreal in July 1970.

Under the provisions of this agreement, Canada will lend a total of $17,500,000 to Hydro Québec to assist in financing the capital cost of the institute, and will make a grant of $325,000 per annum to the institute for ten years commencing when the institute's high-voltage laboratory becomes operational, scheduled for 1971. The loan will bear interest at the rate applicable to funds advanced to federal Crown corporations and is repayable in 25 equal annual installments of principal and interest commencing not later than March 31, 1975.

The agreement recognizes and establishes that the objective of the institute is to meet as effectively as possible the needs of the Canadian electrical industry, including electric utilities and electrical and related manufacturers, and educational and government bodies. To achieve this the institute will provide appropriate research and testing equipment and skilled personnel capable of conducting investigations into equipment performance, materials and techniques related to economic and reliable methods of generating, transmitting, distributing and utilizing electrical energy, and will ensure effective dissemination of research results. In addition, it is provided that the institute shall endeavor at all times to give preference to Canadian clients.

The facilities being provided by the Hydro Québec Research Institute include high-voltage and high-power testing laboratories of a magnitude and capability unsurpassed on a world-wide basis, and currently not available elsewhere in North America.

In accordance with the agreement, a review board and a technical advisory committee have been established. The primary responsibility of the review board is to ensure that the objectives of the institute are achieved. The technical advisory committee, comprising representatives of Canada, Québec, Hydro Québec, and the electrical-power utilities and electrical-manufacturing industry of Canada, reports to the review board, and is empowered to advise the institute as to programs of work and procedures and courses considered desirable to achieve the aims and objectives of the institute. Officers of the Energy Development Sector are members of both the review board and the technical advisory committee.

During the year, loan installments totalling $10,900,000 were paid to Hydro Québec in accordance with the terms of the agreement. The review board and technical advisory committee were appointed and the review board held its inaugural meeting.

Columbia River Development

The Assistant Deputy Minister (Energy Development) continued his chairmanship of the International Columbia River Treaty Permanent Engineering Board, and the federal chairmanship of the British Columbia - Canada Columbia River Advisory Committee. The Permanent Engineering Board is responsible for ensuring that the objectives of the Columbia River Treaty are achieved. Under the treaty three Canadian storage projects were to be constructed. Two of them, namely the Duncan and the Keenleyside (Arrow) dams, have been completed and placed in operation. Construction of the Mica Dam, the largest of the three Canadian projects, is proceeding on schedule for completion in 1973.

The B.C. - Canada Columbia River Advisory Committee assists the federal-provincial committee of ministers involved in the implementation of the treaty by Canada. The Minister of Energy, Mines and Resources is the federal chairman of the ministerial committee.

Nelson River Power Development

The Assistant Deputy Minister (Energy Development) serves as chairman of the Federal-Provincial Nelson River Review Committee established in accordance with the Canada-Manitoba agreement signed in 1967. The agree-

ment pertains to development of the hydro-electric potential of the Nelson River.

Officers of the Energy Development Sector participated with other federal government officials in discussions concerning the supply of AC/DC converter equipment under the provisions of the agreement with a view to achieving maximum benefit to the Canadian electrical industry in the design and manufacture of solid-state converter equipment and the technology associated with the development of this relatively new type of power-transmission equipment, without detracting from the prime objective of the agreement relating to the transmission of Nelson River power to southern Manitoba.

Saskatchewan-Nelson Basin Board

To assist the Saskatchewan-Nelson Basin Board in its studies of alternative water supply and diversion routes, the Sector carried out a study of power costs that would be appropriate for meeting pumping-energy requirements for various alternative schemes. This study was based on the assumption of generation constructed for water pumping only and the alternative of supply purchased from provincial utilities.

High-Voltage Direct-Current Transmission

The Energy Development Sector, in conjunction with other departments and agencies of the federal government, has been assessing progress in this important new area of electrical transmission technology. Apart from activities associated with the Nelson River transmission system mentioned above, this work has included recommendations for financial support and encouragement to Canadian companies active in the development of equipment designs and system-engineering skills.

Thermal Discharge from Electric Generation Facilities

The cooling-water requirements of fuel-fired electric generating plants create concern because of the possibly harmful effects from the discharge of heated water to natural water bodies, especially where water supplies are limited. Arising from this there is an incentive to find beneficial uses for the low-grade heat energy involved. Both aspects have been forecast to the year 2000 by consultants' studies sponsored by the Energy Development Sector of this department and the Department of the Environment. A prime purpose of these studies has been to identify appropriate research well in advance of the actual occurrence of serious problems, and thereby ensure that adequate design and performance standards for thermal-electric generation facilities can be established.

Microwave Communication Facilities

Because of the benefits of large scale in microwave facilities the Department of Communications has been discouraging the proliferation of private microwave systems with the idea that most microwave-communication needs can advantageously be met by common carriers. On the other hand, electric utilities have special needs for extreme reliability and close operational control of communication systems used for operation of interconnected power systems. The Sector assisted the utilities and the Canadian Electrical Association in extensive discussions, the objective of which was to ensure that the special needs of electric utilities are adequately recognized in communication-policy development and in microwave licensing.

Electric Power in Canada

The publication *Electric Power in Canada 1969* was prepared and issued, and material for the 1970 issue and the regional map supplements was assembled. This annual publication of the Department summarizes developments in the generation and transmission of power in Canada. It includes a tabulation of all the major (over 1,500 KW) power developments in Canada, and the location and general particulars of all major transmission lines are illustrated in five regional map supplements.

OIL AND GAS

The Energy Development Sector makes appraisals and policy recommendations concerning the oil and gas industry in terms of developments in the resource, production, processing, transportation, and marketing components. Some issues may be viewed primarily with reference to the domestic economy while others are essentially Canada-U.S. or international matters although all, in the final analysis, are generally quite closely related. Appraisals

and policy recommendations relate to an industry in Canada which, while in existence for well over a hundred years, only became of national importance the past 25 years. It has experienced rapid growth in the past decade when crude oil production increases averaged almost 10 per cent a year, exports increased four times, and petroleum demand within the country advanced at an annual average of five per cent. The growth of natural gas has been even more marked. The government role in relation to oil and gas is widely accepted as necessary for an industry which is now of such national importance but which continues to operate as a free enterprise.

Frontier Resource Development

Emphasis in exploration for oil and gas is now directed to the "frontier" areas of the far north and the east coast offshore. In December 1968 the government established the Task Force on Northern Oil Development as an interdepartmental co-ordinating and advisory group. Under the chairmanship of the Deputy Minister of Energy, Mines and Resources, the task force conducts appraisals relating to pipeline engineering, environmental control, marine transportation, oil and gas marketing, and the economic impact of northern oil development and pipeline activity. Based on its appraisals, it makes policy recommendations to government. Recommendations made in mid-1970 concerning policy guidelines for northern pipelines were published in August of that year to provide industry with a set of standards for planning the construction and operation of pipelines from Arctic regions to southern markets. The task force has become increasingly active as preparatory work by three competing groups has proceeded towards the stage of application to build a northern gas pipeline, while another group of companies has been doing research in preparation for an oil pipeline. Concurrently, the task force has been carrying out its own environmental, engineering and economic research which will help to prepare the government for the assessment of pipeline applications when received. This research is also being used to develop further guideline criteria for industry in its planning of northern pipelines which will constitute some of the biggest construction projects ever undertaken in Canada.

The Canadian Market for Oil and Gas

About half the crude oil produced in western Canada finds a market within the country, and the rest is exported to the United States. Exports balance imports into eastern Canada from foreign sources. As a matter of national policy, domestic crude oil is used as far east as the Ottawa Valley while refinery products east of that line are produced from abroad. Because of price differentials there is some pressure on the Ottawa Valley line from foreign crude and products, and the cost-benefit implications of maintaining the marketing pattern established under the "national oil policy" in 1961 are under continuing review. In addition to price considerations, this policy review also involves assessments of the security of oil supply to eastern Canada in view of its dependence on foreign oil sources. Marketing studies in general relate to availability of oil and gas from various sources, price and changing patterns of demand.

Canada-U.S. Oil Relations

The United States is the sole export market for Canada's oil and gas and, consequently, the terms and conditions of this trade are of considerable importance, inasmuch as petroleum exports for the calendar year 1970 were valued at over $740 million and gas exports at $210 million. Among discussions held between the two countries regarding oil and gas were those which took place as part of the November 1970 meeting of the Canada-U.S. Committee on Trade and Economic Affairs. The continuing analyses under way on the allocation of oil and gas to the export market have regard not only to export opportunities but also to foreseeable domestic market requirements.

Environmental Concerns

The production and use of petroleum and natural gas involve many activities in which special care and high standards are required in order to minimize environmental hazards. In co-operation with the Department of Indian Affairs and Northern Development and the Department of the Environment, the Department of Energy, Mines and Resources is participating in an environmental field and research program relative to northern pipelines from which environmental standards are being developed as part of the country's northern pipeline policy. Other environmental concerns include those relating to the opening of the Athabasca tar sands and to the establishment of appropriate emission standards for the control of pollution from automobiles. Analyses of the impact of environmental hazards have regard to benefits and the costs of environmental control, the costs being considered part of the cost of energy.

International Interests

The Energy Development Sector began to study all aspects of the international oil and gas industries in order to

provide a world-wide perspective for policy recommendations concerning the Canadian oil and gas industries. Rapid developments on the international scene can have a marked effect on the domestic industry, and consequently we must understand current and expected trends in the international oil and gas economy. International events are also followed through participation in the work of such organizations as the Oil Committee of the Organization of Economic Cooperation and Development (O.E.C.D.) and the World Petroleum Congress.

Oil and Gas Policy Studies

Towards the end of the period under review, plans were completed for a major energy policy study which is designed to include an examination of existing oil and gas policies and recommendations as to new policy directions.

COAL

With respect to Canada's coal resources, the Energy Development Sector is responsible for developing sound policies and programs for the orderly, long-term use of this energy resource.

Such policies and programs cover a widely dispersed industry located in western Canada and the Maritimes and exhibiting a broad range of problems related to the extraction, preparation, transportation and marketing of coal. The strongly rising level of exports is adding an international dimension to Canadian planning for coal.

In this complex situation the co-ordinating role of the Energy Development Sector is of key and growing importance for ensuring that the full capabilities within the federal government are efficiently applied in rational programming for coal.

Departmental Committee on Coal

The Energy Development Sector has established the Departmental Advisory Committee on Coal for coordinating federal expertise and facilities related to coal. The committee also maintains liaison with the industry.

Support of Research and Development

In line with departmental policy the Energy Development Sector has resumed the issuing of grants, formerly administered by the Dominion Coal Board, to universities and other research centres for investigations related to coal resources. A sum of $100,000 was made available for this purpose in fiscal 1971-72 and, of this total, grants have already been issued in the amount of $75,160 to four research centres across Canada.

The Canadian Conference on Coal

The Sector takes a leading part in the organization of these annual conferences on coal in co-operation with the Coal Association of Canada and the Canadian Institute of Mining and Metallurgy. The 23rd Canadian Conference on Coal was held in Ottawa on September 19 to 22, 1971.

Co-operation with DEVCO

The Energy Development Sector has assisted the Cape Breton Development Corporation in developing a number of operational options for one of the Corporation's major collieries. These several options were evaluated for technical-economic feasibility by a committee appointed for that purpose and chaired by an officer of the Energy Development Sector. The findings and conclusions of the committee have been reported to the president and board of directors of the Corporation.

The MacBean Mine, Nova Scotia

In co-operation with the Department of Mines of Nova Scotia and Thorburn Mining Limited, the Energy Development Sector has participated in planning the orderly closure of the MacBean Mine. Federal financial assistance was obtained to cover operational losses during the remaining period of mine operation and to support certain reclamation work following closure. As also required under a Canada-Nova Scotia-Thorburn agreement of October 1971, the Province of Nova Scotia and Thorburn have assumed full responsibility for conducting the closure. The Department of Energy, Mines and Resources is overseeing federal financial aid and will also provide technical advice when requested.

The New Brunswick Coal Industry

The Sector has provided advice for improving techniques in surface mining and for a more detailed method for cost management and control.

The Western Coal Industry

The Energy Development Sector has continued to provide advice to coal exploration and mining companies. Consultation has included general discussion, covering the entire region, with coal consumers and companies considering the inclusion of coal in their operating sphere, and detailed evaluations from the exploration phase through mining, beneficiation and carbonization.

The Sector participated in the feasibility review of a research centre at Clover Bar in Edmonton.

Dominion Government Coal Blocks

The Sector has continued its involvement in the problems related to the development of the Dominion Government Coal Blocks in British Columbia and the evaluation of proposals put forward by prospective mining companies.

URANIUM AND NUCLEAR ENERGY

The uranium and nuclear energy industry in Canada embraces many activities, including exploration, mining, processing of ore, conversion of mill product to usable forms, fuel fabrication, reactor design and construction, reactor operation, and finally, to complete the cycle, the disposal of the spent fuel. With such a multi-faceted industry, it is not surprising that many federal departments and agencies participate in various ways to ensure that the industry is developed in an over-all manner beneficial to the country. The need for sound, flexible national policies and guidelines is further emphasized by the strategic importance of uranium, Canada's large uranium reserves, the long-term economic significance of uranium as a domestic energy source, and the future potential of uranium as a major export commodity.

The Energy Development Sector is engaged in the development and formulation of policy on uranium, nuclear energy and associated matters. Of particular interest are an assessment of international markets for uranium, a study of the feasibility of establishing a uranium-enrichment plant in Canada, the management of the uranium stockpiles that have been added to because of a recent agreement with Denison Mines Limited, and regulations limiting foreign ownership of the Canadian uranium industry.

International Markets for Uranium

Canada has more than 20 per cent of the Western World's proven reserves of uranium available at less than $10 per pound U_3O_8, and in 1970 this country produced about 20 per cent of the world's output, valued at more than $50 million. The industry is producing at a level considerably below its present capability, a situation which may exist for several years. The international market is growing rapidly, however, with the demand for uranium doubling every four or five years. Hence, in order to make long-term policies for the orderly growth of the uranium industry, it is important for the federal government to have an accurate assessment of the international supply-demand picture as well as up-to-date information on market price. Such information is being assembled by the staff in the Sector.

Uranium Enrichment

In-depth studies have been initiated on the question of the feasibility and desirability of establishing a uranium-enrichment plant in Canada. The subject was discussed during a mission led by the Minister to Japan. The mission to Japan served to acquaint officials from both private industry and government with the uranium requirements of that country and the attitude of the Japanese government and industry concerning possible co-operation with Canada in the enrichment field.

Uranium Stockpiles

During the period 1963-1970 the federal government spent $101 million for stockpiles of uranium, totalling 19 million pounds U_3O_8. A further $39 million will be spent in the years 1971-1974 accumulating 6.3 million pounds from a joint program with Denison Mines Limited, the largest Canadian producer of uranium. A joint stockpile program was initiated in 1971 to ensure the basic economic security of the Elliot Lake community where Denison is the major employer. A new Crown corporation, Uranium Canada, Limited, was incorporated in 1971 to act on the government's behalf in the acquisition and later disposal of the stockpile.

Foreign Ownership in the Canadian Uranium Industry

The question of foreign ownership of uranium mines in Canada is an important element in considerations being given to foreign ownership of Canadian industries in general. Canadian government policy limiting the proportion of foreign ownership in Canadian uranium production stipulates that owners of companies engaged in duly authorized exploration for uranium on March 2, 1970, and owners of producing companies will be permitted to retain their holdings. However, any sales of such holdings must be to Canadian residents until the total foreign ownership is reduced to 33 per cent. Also, no foreign investor, or group of associated foreign investors, will be allowed to retain more than 10 per cent ownership in a property. The Department has been given the task of co-ordinating the preparation of regulatory measures required to implement this policy.

RESOURCE MANAGEMENT AND CONSERVATION BRANCH

The Resource Management and Conservation Branch was established during the year, replacing the Resource Administration Division, in accordance with the Department's increasing responsibilities in the management of Canada's mineral resources.

This new Branch makes recommendations and provides advice on the handling of offshore mineral resources to government and private agencies. It administers the federal interests in mineral resources off the east and west coasts and in Hudson Bay and Hudson Strait, as well as those federally owned mineral rights in the provinces which become available for development. In doing so, the Branch designs, issues and administers various types of terminable offshore permits taking into account the special conditions of the offshore environment; establishes requirements concerning operations, production, conservation and pollution control; makes sure that companies carrying out offshore exploration comply with these requirements; and evaluates the mineral potential of offshore areas as a basis for management policy. The Branch also formulates policies and makes regulations concerning federally owned mineral rights in the provinces, and administers them.

Canada's submerged continental margin, which includes the continental shelf and the continental slope beyond, is the second-largest in the world, after that of the Soviet Union. It comprises about two million square miles, which is more than half as large as Canada's entire land area. Of this the largest part lies off the east coast, about 400 thousand square miles lie in Hudson Bay and Hudson Strait, 50 thousand square miles lie off the west coast, and the remainder is in the high Arctic, in the Beaufort Sea and Arctic Archipelago regions.

Although not all of Canada's offshore areas are prospective for mineral resources, it has been estimated that as much as half of Canada's remaining recoverable reserves of oil and gas are located beneath Canada's submerged continental margins, particularly beneath that off the east coast and the north. The petroleum industry, which for many years has concentrated its exploratory efforts in Canada's Prairie Provinces, is now shifting its attention to the offshore and to the Arctic, both of which frontier regions are now experiencing an unprecedented wave of exploration. The potential for offshore mineral resources other than oil and gas is also promising. However, in Canada as in other regions, offshore mining is not as far advanced as the offshore oil and gas industry.

At the end of the fiscal year 1971, Canada Oil and Gas Permits covered about half the area of the Canadian submerged continental margin. These offshore permits are issued and administered under the *Canada Oil and Gas Land Regulations,* which are now undergoing extensive revision.

Operational Controls

During the fiscal year, a new bill amending the *Oil and Gas Production and Conservation Act* was passed which extends comprehensive statutory authority governing operation, production and conservation matters to the offshore. The Act now provides for wide statutory authority over all offshore oil and gas activities, covering exploration and drilling for, and the production, conservation, storage, transmission, distribution, measurement, processing, and other handling, of oil and gas produced offshore. Although the primary objective is the protection of human life, the prevention of pollution of the marine environment

and the conservation of oil and gas resources, those aspects concerned with production matters are also important. Among them are requirements for pooling and unitization of productive areas, with production therefrom carried out in accordance with optimum engineering practice, so that costs are kept as low as possible to help make the oil and gas produced competitive in world markets.

The Department has the authority under the *Oil and Gas Production and Conservation Act* to shut down operations in the interests of safety or pollution prevention and to prohibit their resumption until adequate remedial steps have been taken. The Department, through the Resource Management and Conservation Branch, is even empowered to take over management and control of an operation at the operator's cost if, in the opinion of Branch officials, satisfactory steps are not being taken to remedy the situation. Penalties are provided for contravening the Act.

In brief, operators are required to: submit notices of proposed programs; provide information and appropriate materials on a current basis; assist in the carrying out of inspections by authorized officials; furnish comprehensive technical reports; and support claims for refunds of guaranty deposits with certified statements of expenditures. Thus, all parties carrying out offshore work must not only obtain prior authorization before the commencement of each program of operations, they must submit reports on these operations on a current basis, and they must submit information and materials obtained as a result of the work. The large volume of offshore materials and technical information, including well logs, cores, and cuttings, submitted under the Canadian regulations is then processed, curated and stored to ensure its preservation. Upon the expiration of appropriate periods of confidentiality the materials and information are made available to the public in a proper form and manner.

Federal authorities maintain control over offshore activities by means of a system that provides a number of safeguards. Before undertaking an offshore exploration program, a company must first submit for approval by the Branch a comprehensive *Offshore Program Notice* describing the proposed work in detail, for example, each seismic survey. Drilling an offshore well involves special requirements. A well cannot be drilled until the authorities have approved an *Offshore Drilling Notice* setting out in detail the company's proposed drilling plans. The actual drilling is then subject to supervision by Branch officers. In this regard, officers inspect each drilling location in order to ensure that federal requirements are being met. When a well has reached total depth, Branch approval must be obtained for the manner in which it is to be completed, suspended or abandoned.

In recognition of the special nature of the vulnerable offshore environment, the Branch maintains a system of coordination between industry and governmental agencies involved in the utilization of the offshore. Its primary purpose is to ensure that the special requirements of governmental agencies with offshore responsibilities are made known to industry and that industry in turn meets these requirements. Several agencies in addition to the Department of Energy, Mines and Resources have practical responsibilities related to the offshore, and each of these agencies receives advance notice of proposed offshore activities so as to allow time for appropriate action. The Department of the Environment receives 90 days notice; the Department of Transport 60 days notice; the Department of National Defence 45 days notice.

East Coast Regional Office

During the fiscal year, supervision and control of all oil and gas activities off the east coast, particularly exploratory drilling, were carried out under the Oil and Gas Production and Conservation Act, using the Branch's new regional office in Dartmouth, N.S., as a base of operations. A laboratory associated with this office was opened in 1970 to handle the cores, cuttings and other materials from wells drilled off Canada's east coast and in the Hudson Bay and Hudson Strait regions. These materials are now being received, processed and curated at this laboratory, where they are made available for examination, after the expiration of associated confidential periods, to interested scientists. By the end of the fiscal year, plans were being finalized to construct a $100,000 addition to this office-laboratory building, in order to accommodate a team of subsurface experts affiliated with the Geological Survey of Canada who will carry out micropaleontological, palynological, sedimentological and stratigraphic analyses of cores and cuttings from east coast offshore wells. The results of these studies will assist the Branch in fulfilling its responsibilities.

In Canada's offshore regions it is particularly important that well materials are properly handled, processed, curated and analysed, since they have been obtained at great cost, and are often the only tangible asset remaining after the drilling of an unsuccessful well. In particular, their valuable microfossil and spore content, which is vital for age-dating, stratigraphic correlation and interpretation of sedimentary environments, would soon be depleted

and lost permanently if not properly extracted and curated.

Canada is one of the few nations in the world in which industry is required to submit to the government complete suites of rocks, fossils and mechanical logs obtained in drilling for oil and gas. These materials provide an important record of our sedimentary basins, which can be referred to time and again in the never-ending search for strategic fossil fuels and other minerals. The results of the studies carried out in the new laboratory will not only assist the Resource Management and Conservation Branch in fulfilling its responsibilities as regards the development and conservation of offshore mineral resources, they will provide a regional biostratigraphic and sedimentological framework for Canada's Atlantic continental margin, and the dissemination of such information will help stimulate and sustain the optimum development of Canada's offshore mineral resource potential.

Offshore Activity - 1970

During 1970, oil companies spent $37 million in the evaluation of offshore Canada Oil and Gas Permits administered by the Branch, which constitutes an increase of $15 million over 1969. Of this amount, $13 million was expended for geological and geophysical surveys, and $24 million for exploratory drilling. Cumulative industry expenditures in Canada's offshore to the end of 1970 (excepting the high Arctic) reached $117 million, including $58 million for geology and geophysics and $59 million for drilling. During 1970, the Branch approved 80 separate offshore exploration programs, which were subsequently monitored by Branch officers to ensure that they were carried out in accordance with federal requirements.

Highlights of 1970 industry activity included:

(1)Continuation of Shell's exploratory drilling program on the Scotian Shelf. The semi-submersible offshore drilling unit SEDNETH 1, which commenced this program in September 1969, was joined in May 1970, by a second and even larger semi-submersible unit, the SEDCO H, which was constructed in Halifax Shipyards by Hawker Siddeley Canada Ltd. for Southeastern Commonwealth Drilling Limited at a cost of $13 million. Twelve wells were completed and subsequently plugged and abandoned during 1970 by these two rigs, and drilling was progressing at two additional sites at the end of 1970. No commercial discoveries were made during the year, although significant showings of oil and gas were encountered in a number of wells.

(2)Completion of construction of a second large semi-submersible offshore drilling unit by Halifax Shipyards, the SEDCO I, in December 1970. This unit, which is identical to the SEDCO H, was contracted to Amoco and Imperial for a continuous drilling program on the Grand Banks that was to commence in April 1971.

(3)Start of construction in Halifax Shipyards of a third offshore drilling unit, the SEDCO J, identical to the H and I units, for completion in late 1972 at which time it will be contracted to Mobil Oil Canada for a drilling program on that company's permits off the east coast.

(4)Drilling of two exploratory wells in the Gulf of St. Lawrence east of Prince Edward Island by Hudson's Bay Oil and Gas Company and Petrofina Canada, using the WODECO II drilling barge, a much smaller unit than the SEDNETH and SEDCO units.

(5)Drilling of two onshore wells in the Gulf of St. Lawrence region on Anticosti Island and on Brion Island. These wells were immediately adjacent to offshore Canada Oil and Gas Permits in the Gulf and contributed significantly to the evaluation of these permits.

Canada Oil and Gas Permits

The Branch issued 489 Canada Oil and Gas Permits covering 28.3 million acres during the fiscal year 1970-71, all off the east coast. This brought the number of offshore Canada Oil and Gas Permits administered by the Branch to 5,909 as of March 31, 1971, covering 413.7 million acres as follows:

East coast .... 3,906 permits - 287,359,292 acres
West coast .... 207 permits - 13,844,284 acres
Hudson Bay - Hudson Strait 1,796 permits - 112,547,345 acres

The total revenues received during the fiscal year 1970-71 from offshore permits, including permit fees, transfer fees, forfeitures, exploratory licences and maps, amounted to $269,448.99, most of which was derived from permit fees.

Mineral Claims

Offshore mineral claims for mineral rights other than oil and gas rights are recorded under the *Canada Mining Regulations*. No offshore mineral claims were recorded during the fiscal year. The total number of mineral claims in effect was 206, as follows: East coast: 82; West coast: 42; Hudson Bay: 82. Total revenues received from prospecting licences during the fiscal year 1970-71 amounted to $281.62.

Federally-owned Mineral Rights in the Provinces

During the fiscal year 1970-71, 15 oil and gas leases were issued (10 in Alberta, 5 in Manitoba) bringing the total number of federal oil and gas leases in the provinces to 216, as follows: 113 in Alberta; 62 in Saskatchewan; 37 in Manitoba; 4 in Ontario. In addition, two leases for minerals other than oil and gas are held in Ontario. On March 31, 1971, 69 oil and/or gas leases were productive as follows: 37 in Alberta; 22 in Saskatchewan; 9 in Manitoba, and 1 in Ontario. The total revenues received during the fiscal year 1970-71 from oil and gas leases, including royalties, lease sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $285,430.22, most of which was derived from royalties.

Mineral Development Sector

MINERAL RESOURCES BRANCH

The Mineral Resources Branch carries out a continuing review of the role of minerals in the Canadian economy. The Branch advises government planners and policy-makers on ways and means to utilize minerals in a manner that will contribute to the economic and social well-being of the Canadian people while maintaining a progressive industry.

Activities carried out in the Branch may be regional, national or international. The interrelationships between exploration, processing, development, transportation, marketing receive constant attention, owing to their effect on the state of the mineral industry in its world setting. Comprehensive studies on minerals are carried out that include: the effects on regions; developments in the mineral industry; analysis of government policies affecting the mineral industry, including taxation and legislation; harmonization in the development of multiple resources; and developments in foreign mineral industries.

The Branch comprises four divisions, namely, Minerals and Metals, Resource Development, Mineral Economics Research, and Administration.

Review of Governmental Policies Affecting Minerals

There is increasing public interest in the potential contribution of mineral resources to the well-being of Canadians. Also, expanding foreign and domestic demands are placing greater pressures on Canada's finite mineral and related resources. Consequently, a comprehensive review of existing policies affecting minerals and how they contribute to or complement other economic and social policies was initiated. In general, the aim is to increase the economic and social benefits to Canadians from the industry. Specifically, it includes such matters as ensuring a mineral supply for national needs; preparing an inventory of Canadian mineral-resource potential; improving mineral conservation and use; improving returns from exportable mineral surpluses and developing practices for efficient multiple resource use.

Branch members seek to identify the objectives of a minerals policy and the needs for inter-agency collaboration. Plans are afoot to increase the staff engaged in forecasting so that the consequences of alternative policy options can be better assessed.

Taxation and Foreign Ownership

The government continually consults the Branch on the taxation of the mineral industry.

The Government Task Force on Foreign Ownership requested the Branch to participate in that part of its study dealing with the resource-based industries. Analyses were made of the foreign-ownership policies and economic-development strategies of countries buying or selling minerals. In addition, the Branch keeps an eye on the sources and availability of capital for the Canadian mineral industry and on Canadian ability to supply minerals at different

levels of processing. The Branch produced a study on laws covering disclosure requirements of mineral companies operating under various jurisdictions in Canada. These studies will contribute to the review of Canadian minerals policy as well as to an improved understanding of foreign ownership.

Environmental Quality

The effects of mining and processing on the environment led to a concern about measures to deal with this matter. The basic challenge is to harmonize development with environmental-quality objectives. A number of inquiries were made, including preliminary studies of the Foothills coal region and of mine health and safety. The Branch also made an inventory of the environmental impact of energy production and exploration as a contribution to the energy-policy study.

Social Development

Although mineral resources contribute to social development by creating jobs and often entire communities in the remote areas of the country, there may also be social problems for communities when a mine ceases operations. The Branch administers the Emergency Gold Mining Assistance Act (EGMAA), which was designed to minimize the social and economic hardships in a number of communities dependent on gold mining, which is rapidly declining.

An amendment to the Act in 1963 contained a restriction limiting eligibility for assistance, in the case of lode gold mines commencing production after June 30, 1965, to those providing direct economic support to an existing mining community. A gold mine is deemed to provide such support if more than 50 per cent of the persons employed at the mine reside in the established mining communities listed in a schedule to the Act.

Further amendments to the Act which received Royal Assent on February 11, 1971, resulted in the following changes:

1. The application of the Act was extended to June 30, 1973.
2. A gold mine, other than a placer mine, had to be in reasonable commercial production in the month immediately preceding August 7, 1970.
3. A gold mine that was not a placer mine was required to agree in writing to:
   a) conduct all future hiring through Canada Manpower Centres,
   b) give notice of a mine closure at least four months prior to cessation of operations,
   c) retain, immediately following notice of closure, the Manpower Consultative Service of the Department of Manpower and Immigration to assist in the placement of employees as they are laid off.

The number of lode gold mines receiving assistance under the Act has declined from 87 in 1948 to 30 in 1970.

The amount of assistance payable to an operator depends on the amount by which the average of production exceeds \$26.50 per ounce. When calculated on the basis of all eligible ounces produced, the maximum assistance payable amounts to \$10.27 per ounce.

The amounts paid to gold mine operators to March 31, 1971, for the years 1948 to 1970 inclusive totalled \$288,592,320.47 on a production of 60,240,260.105 fine ounces of gold.

Figures for the calendar year 1970 are not yet complete, but the total expectation is approximately \$14 million.

Regional Development and Mineral-Based Activities

Mineral-resources activities may help significantly to reduce regional economic disparities, both in terms of income and employment. Indeed, it is becoming increasingly apparent that proper mineral-resource-management strategies can provide the basis for much self-sustained regional economic growth. One major aspect of such development is the diversification of the regional economic base through development and further processing.

The Branch co-operates with many other federal and provincial agencies in this area. Projects include: the analysis of further-processing opportunities for Canadian metal production with forecasts for the next five years; a *Northwest Canada Resource Transportation Study* in co-operation with the Department of Transport to examine the extension of transportation networks in northern British Columbia, Yukon and Northwest Territories; a *Study on the Potential Outlook for Bulk Commodity Movement Through Various Canadian Ports* in co-operation with the National Harbours Board; a mineral-development program for New Brunswick in co-operation with both the province and the Department of Regional Economic Expansion—to date, this program has resulted in potash and salt deposit discoveries; a similar program for New-

foundland is now being negotiated; an evaluation of the economic mineral potential of Manitoba in co-operation with the province; and preparation of a study of mining legislation and land-use regulations in the north.

Foreign Aid and Research Grants

The Branch, on behalf of the Department, contributes to the Canadian International Development Agency's foreign aid. It provides departmental co-ordination through advice and/or evaluations on proposals for capital projects in other countries and in the selection of experts for foreign-aid projects abroad. For example, an assessment of the economic potential of foreign deposits was undertaken by the Branch.

The Department, through the Branch co-ordinator, made recommendations on applications to the Canadian International Development Agency for technical training of foreign students. These programs were sponsored through the various regional plans of the Agency and through the United Nations. Practical training was arranged partly within the Department of Energy, Mines and Resources and also in private industry, provincial government departments and university graduate schools.

The Branch established a modest grants program to encourage and support mineral economic research in Canada, including exploration, mining, and mineral processing and product distribution. However, applications are also invited from a wide range of other social-science disciplines (sociology, law, political science, social geography) that may contribute to a better understanding of the principles of mineral-resource supply and demand, or of mineral-resource management. Both theoretical and practical studies are of interest, but special consideration will be given to those dealing with policy problems confronting Canadian mineral-resource management and development. Studies may focus on a commodity or a region.

Mineral-industry Analysis

Research in this area provides much of the factual and analytical foundation for many of the other activities in the Branch and for the advice and recommendations relating to the economic performance and management of the mineral industry. In general, economic analysis is conducted on such factors as resource-supply adequacy, exploration, mining, smelting, refining, uses, prices, trade, tariffs, foreign developments and other aspects which may vary among mineral commodities. Forecasts play a vital role, especially since mineral-commodity and industry activities have a diverse set of policy implications on many of the national issues of concern to the Branch. This work frequently involves the Branch in international meetings. For example, the Department is represented through the Branch at the OECD International Lead-Zinc Study Group, the European Nuclear Energy Agency (ENEA), OECD Joint Ad-hoc Group Energy Committee and Industry Committee on Coking, and the International Tin Agreement meetings.

The following studies are characteristic of the many facets of the mineral industry studied: short-term forecasts of the production of Canada's major metals and industrial minerals; a review of problems associated with the world oversupply of sulphur and its relation to Canadian production and future pollution-abatement measures; commodity forecasting techniques (demand and exports) illustrated by zinc; the examination of a number of world supply-and-demand problems in copper, coal, nickel, potash, in close co-operation with the Department of Industry, Trade and Commerce; a study of the Canadian cement industry; and the production of a potash trade map to illustrate world production and trade in this vital fertilizer material.

EXPLOSIVES DIVISION

Following an alarming number of serious accidents in the early 1900s, it was evident that some control over the explosives industry was necessary to safeguard both the industry's workers and the public. As a result, the Explosives Act was introduced in 1911 and passed by Parliament in 1914. Proclamation was delayed by World War I until 1920. The Explosives Division of the then Department of Mines had been formed the previous year to administer the Act.

The immediate and continuing acceptance by the industry of the imposed controls has made the explosives industry one of the safest in Canada. This is clearly shown by the significant reduction in accidents during the intervening years. In the four years prior to the introduction of the Act, in manufacture alone, some 42 fatalities occurred during the production of an estimated 20,000 tons of explosives; in contrast, in the past four years there has been but a single fatality in the production of over 655,000 tons.

The primary objective of the Division is to protect the employees of explosives factories and all those who regularly or even occasionally handle store, transport and use explosives, and by so doing directly safeguard the public at large. An explosive includes any substance that is made, manufactured, or used to produce a violent effect by explosion or a pyrotechnic effect. The Division therefore is responsible for all factories that produce commercial blasting explosives, military explosives, blasting accessories, gunpowder, smokeless powders and percussion primers, ammunition, fireworks and other pyrotechnics, and for the quality and safety of their products. This responsibility extends also to the road transportation of these items and to their storage and importation.

Control is exercised by a system of licences, permits and sales records supported by inspections by members of the Division and by the Royal Canadian Mounted Police. All licences and permits are issued from the Ottawa office.

A general quickening in construction and mining activity during the year was reflected in an increased office and inspection workload with which the Division was just able to cope. The number of factory licences continued to increase as expected, reaching a total of 55 by year end, mainly due to the expansion of on-site slurry or water-gel manufacturing facilities at additional open-pit mines. However, two factories manufacturing sporting ammunition ceased operations during the year. Similarly, the number of licences issued for the storage of blasting explosives in support of construction projects, road building, seismic exploration, pipeline laying, erection of transmission towers, forestry and like operations rose to more than 1,200. Licences issued to vendors of explosives remained relatively constant at about 400. In addition, more than 400 explosive transportation permits were issued to explosives distributors and owners of other commercial vehicles for the haulage of explosives in support of these activities.

A new hobby for youth — model rocketry — has been rapidly gaining popularity. By year end, 39 licences had been issued to hobby shops across Canada to permit the sale of model rocket engines to individuals licensed as firing supervisors by the Canadian Association of Rocketry, a division of the Youth Science Foundation of Canada. The small rocket engines used in this sport consist of a propellant explosive, and although relatively innocuous in themselves, even if involved in a fire, can accelerate to the speed of a bullet shortly after launch and can push a rocket to heights in excess of 2,000 feet. These properties make them a hazard to aircraft or to the public if misused.

Except for the one fatality mentioned previously which occurred during the manufacture of a military explosive, the year has been exceptionally accident-free. Even though many incidents were reported during the manufacture, handling, storage and transportation of explosives, few injuries were sustained and these were all minor, and the over-all property damage was minimal. Since the actual use of explosives is beyond the purview of the Explosives Act, data on explosives accidents occurring under such circumstances are not included.

Members of the Explosives Division promote safety programs and regularly meet with members of industry, federal and provincial government agencies, municipal authorities and other groups involved with the handling of explosives. The Division also has available for distribution safety literature on the storage, handling and transportation of explosives.

A separate, more detailed report of the activities of the Explosives Division is published periodically.

Science and Technology Sector

SURVEYS AND MAPPING BRANCH

The past fiscal year has seen satisfying progress in the Surveys and Mapping Branch's efforts to provide maps and surveys for the development, administration and protection of Canada. Two projects in particular, because of their vast scope and impact, caught the attention of the general public. These were (a) the air photography of the prairies which was taken during the first two weeks in August in support of the LIFT (Lower Inventories for Tomorrow) Program; and (b) the start of the detailed mapping of the Mackenzie River valley, the so-called pipeline corridor. Further details of these and the more routine programs of the Branch are given in the directorate reports that follow.

GEODETIC SURVEY OF CANADA

Twenty-two field parties established horizontal and vertical control to extend and densify the existing national control-survey framework and to provide control for the national mapping program. In addition, the Survey continued its activities in investigational work.

The extension and densification of the first-order horizontal-control framework was carried out in Yukon and Northwest Territories and four provinces. In the Territories the aerodist network was extended westward from the Yukon-Northwest Territories boundary between the Porcupine River and the Arctic coast; and eastward, between Great Bear Lake and the Arctic coast, to connect with the existing Yellowknife Coppermine control network. This project covered 91,200 square miles and provided horizontal mapping control for three hundred and eighteen 1:50,000 map sheets. In Alberta a network was established to control and co-ordinate municipal surveys in Fairview, Grimshaw and Peace River. In Ontario the control network in southwestern Ontario, along the north shore of Lake Erie, was completed to Dunnville, and a small network was established to control municipal surveys in Sault Ste. Marie. In Quebec, in co-operation with the Quebec Department of Lands and Forests, the densification of the existing control framework was continued in the area between Quebec City and Trois Rivières. In Nova Scotia the central loop of control was completed between Annapolis Royal and Liverpool and a new network started from Halifax toward the Strait of Canso.

First-order levelling was carried out in five provinces. In British Columbia a line was extended from Mica Creek down to the Columbia River to Needles on the Arrow Lakes; in the course of this work a reciprocal water-crossing of 1.6 miles was made between Shelter Bay and Galena, the longest passage of precise levels across water made by the Geodetic Survey. The Trans-Canada level line was extended eastward from Sault Ste. Marie to Arnprior, thus continuing this major project which was started in 1966 and was to be completed in 1971. In Quebec, levelling of high precision, using the metric system, was continued in the International Great Lakes Datum re-evaluation program. The line was extended eastward from Quebec City to Father Point; a portion of this line also forms part of the Trans-Canada level line. In the Maritimes, lines of levels were run from Glenholme, Nova Scotia, to Dorchester, New Brunswick, and from Truro,

Nova Scotia, to Waverley. First-order vertical-control grids were established in Halifax-Dartmouth and Montreal and in the southeast part of the National Capital area. A small party checked the stability of 81 Hydrographic Service water-gauge sites between Father Point, Quebec, and Thunder Bay, Ontario. Eighteen deep benchmarks were established near gauge sites where the stability of normal benchmarks was questionable.

Three astronomic parties established eleven Laplace azimuth stations, two sets of intervisible Laplace azimuth stations and twelve plumb-line-deflection stations at various locations throughout the country. The precise astronomic position of the satellite-triangulation station at Cambridge Bay, N.W.T., was also determined. The joint Canada-United States satellite-triangulation program was resumed in October. A combined Canadian-American team manned the station at Whitehorse, and a similar team, including surveyors from the Canadian Armed Forces, manned the station at Cambridge Bay.

The assistance to provincial and municipal authorities in establishing rectangular co-ordinate survey systems was continued at a reduced level. Traverses were run at Hay River to control legal surveys and town-plan mapping. In southern Ontario the co-operative program with the Ontario Department of Highways was completed with the establishment of second-order traverses control in the Windsor-Leamington-Ridgetown area. A second-order municipal control grid was established in Sault Ste. Marie and the control grid in Halifax was strengthened and densified.

A helicopter-supported party established horizontal control for 1:50,000 mapping in a large area of the District of Keewatin between the 60th parallel and Baker Lake. Vertical and horizontal control for 1:25,000 mapping was established in the area of the new Ste. Scholastique airport in Quebec.

Research was carried out on methods of integrating existing low-order horizontal and vertical control surveys into the national networks, and an investigation into gyrotheodolites was carried out. The latter proved particularly interesting when it was discovered that, with a special electronic readout system designed and built in the Branch, azimuths can be obtained that are virtually as accurate as first-order astronomic observations.

LEGAL SURVEYS

The Legal Surveys Division continued its statutory general management and technical control of all legal surveys in Indian Reserves, National Parks and the Territories.

The Division had 18 survey parties in the field and, in addition, contracted work to 25 survey firms in private practice to complete as many as possible of the projects required for the federal government. They worked on 94 projects in Indian Reserves in all of the provinces except Newfoundland and Prince Edward Island, and 23 projects in National Parks. In addition, technical instructions were issued for 151 surveyors on Crown Canada Lands for provincial and private agencies.

In the Territories, co-ordinate control work was carried out at Whitehorse and Yellowknife, and 30 legal surveys were made at other locations throughout the north.

Two federally appointed commissions, chaired by the Surveyor General of Canada Lands, were involved in the survey and maintenance of provincial boundaries. The Manitoba-Saskatchewan Boundary Commission continued the resurvey of the southerly 240 miles of that boundary. This year's work included the survey of 43.6 miles of boundary and clearing of a further 18 miles through heavily wooded country. The British Columbia-Yukon and Northwest Territories Boundary Commission reviewed the use of defoliant spray on the boundary and decided that no further maintenance work should be carried out for the year 1971-72.

TOPOGRAPHIC SURVEY OF CANADA

Photogrammetry Division

During the past year the Division forwarded for reproduction 513 National Topographic Series maps. This total was comprised of 263 new maps and 250 revised maps. Twenty-eight field parties carried out field-completion work, mainly on revision map sheets. In addition, two engineering field parties carried out horizontal and vertical quality checks on a number of 1:50,000 maps.

The new mapping highlight of the year was the compilation of 120 maps at the scale of 1:50,000 in the Mackenzie River area, commonly referred to as the pipeline corridor. These maps were completed to an enhanced advance-print stage (i.e. suitable for monochrome reproduction and distribution) during a six-month period commencing December 1, 1970.

Photomaps were produced to meet the needs of northern development, geological exploration and provincial map-

ping. The Division produced 425 sheets, ranging in scale from 1:5,000 to 1:250,000. The development of the Gestalt Orthophoto System in Vancouver during the year has made posible 1:50,000 photomapping of more rugged areas than heretofore possible.

Consultant services on photogrammetric mapping were supplied to other federal agencies on a steadily increasing scale. These services included providing technical advice, identifying the needs, writing technical specifications, and inspecting and monitoring contracts awarded to the aerial-survey industry.

The Research and Development Section initiated two major projects that are likely to have a profound impact on the mapping of the country. The first, carried out in co-operation with the Institute for Photogrammetry of the University of Stuttgart, West Germany, is the development and testing of a new method of aerotriangulation and analytical adjustment for photogrammetric blocks of unlimited size. This development will further reduce the need for ground survey points. The second project is the partial automation of the map-compilation process. In addition, techniques in photomapping were improved, research in the use of high-altitude photographs for topographical mapping was continued, and a photogrammetric test area was created near Ottawa.

Aerial Photography Division

During the period under review, 8,295 requisitions requesting photographic work were forwarded to the Air Photo Production Unit for processing. The Ottawa office issued 7,283 requisitions, the Calgary office 894, and the Canada Centre for Remote Sensing (established July 1) issued 118 requisitions. These requisitions requested contact prints, enlargements, glass and film diapositives, transparencies, index maps, film processing and specialized photographic products totalling 764,683 black-and-white products, 23,615 color products, for a total of 788,298 products.

The Ottawa office has on file 3,491,400 photographs, and the Calgary office has 594,926 file copies. The Ottawa office has also started to file negative and positive film generated by the Canada Centre for Remote Sensing.

The National Air Photo Library was used as a reference library by various members of the Department, private industry, educational institutions and the general public. To improve these services, the Library is planning to expand its public viewing facilities and photo-interpretation equipment.

MAP PRODUCTION DIRECTORATE

Aeronautical Charts Division

In 1971, the Aeronautical Charts Division produced 50 different map series and flight-information publications.

A highlight of this year is the conversion from the National Topographic System format of 1:1,000,000 World Aeronautical Charts, which covered Canada with 68 sheets, to a new format. The new format will provide coverage of Canada by 19 sheets, using larger paper and printing maps on the front as well as the back of the chart. Seven of the new-format charts have been published, and it is expected that completion of the conversion will be achieved in 1972.

Another new project is the production of 60 military shaded-relief charts, at 1:250,000 scale, in co-operation with the Mapping and Charting Establishment of the Department of National Defence.

In 1971, the Division supported the London-Victoria Air Race by providing, at very short notice, the revision of 49 aeronautical charts at a scale of 1:500,000 covering the Canadian part of the race.

A new Radar Digital Display System for air-traffic control, which is being developed by the Ministry of Transport, is being supported by the Division. A total of 245 colored video charts has been produced for this system which will be experimentally operational at Moncton by the beginning of 1972. All charts are subject to the 28-day revision cycle established for radio-navigation publications. To cope with the large workload created by this project, programs have been written to use the Computer Graphics System, which is now being developed by the Branch.

A chart has been developed for the purpose of designating and evaluating potential STOL operations between Ottawa and Montreal.

During 1971, 16 more controller charts were taken into production for a total of 64, and 25 more black-and-white video charts to raise the total of this type of presentation to 91.

A new publication to support the visual navigation charts, called the *VFR* (Visual Flying Rules) *Supplement,* has been designed and a prototype has been completed. Production of this publication was to start early in 1972.

Automated Cartography

Development continued in applying computer technology to cartography. A Kingmatic Automatic Plotter was delivered and passed acceptance tests early in the year. Software and cartographic procedures were developed and tested with a view to being operational for production work in 1972. Two pilot projects were completed during the year in order to prove the operation of equipment and the function of software. One of the pilot projects was a 1:50,000 National Topographic Series map which was presented at the Commonwealth Conference at Cambridge, England, in August. This map was received with great interest, and it was acknowledged that Canada is one of the world leaders in this field. New equipment purchased late in the year included two more digitizing stations and a Storage Tube Display Terminal. The digitizing stations will be assigned to production work, while the display terminal will be initially used for experimental work in co-operation with Waterloo University.

Cartography Division

One of the principal tasks of this Division is the drafting and completion of map manuscripts produced by the Topographical Survey Directorate. During the past year, drafting was completed for 45 maps at 1:25,000 scale, 316 maps at 1:50,000 scale and 10 maps at 1:250,000 scale.

Another function is the production of small-scale geographical maps. In the International Map of the World (IMW) series, 19 maps have been printed, and a further 12 maps are in production. A major revision of the popular map of Canada at 100 miles to one inch was published during the year.

The Division also provided cartographic services to other departments. Such services included a revision of a map of the highways of Canada and northern United States, an electoral map of the Northwest Territories, five maps for inclusion in the booklet covering the royal tour of British Columbia, and a map of the world showing Canada's role in the production of potash.

Geography Division

Forty per cent of *The National Atlas of Canada* and *L'Atlas National du Canada* had either been printed as loose sheets or was in color proof or plating by the end of the fiscal year. The remaining material was in various stages, with approximately one year's work required for completion. A special map showing density of population of Canada for 1961, derived directly from the National Atlas, was published in French and English versions.

A series of 91 maps at 1:500,000 covering the country, showing the 1966 hierarchy of census areas, including enumeration areas, was brought to completion. The maps are primarily for Branch use, but are available on plastic or as ozalid prints to the public.

Map Reproduction Division

The map printing for the past year amounted to a total of 39,472,679 impressions. These included 979 topographical maps, 518 aeronautical charts, 36 general maps, 648 departmental maps other than the above, and 277 maps and charts for other departments, being a total of 2,458 maps and charts printed.

TECHNICAL INFORMATION AND SALES OFFICE

Toponymy and Libraries Division

During the 1970-71 fiscal year, the Division, in support of the Canadian Permanent Committee on Geographical Names, investigated 34,768 names, of which 7,281 were new decisions. Geographic nomenclature was checked and verified for 572 new maps, 494 submissions. Various geological maps and tourist travel maps were examined and errors drawn to the attention of the producers. The staff answered 730 inquiries which entailed a significant amount of investigation and research. Provisional editions of the Yukon Territory gazetteer and Northwest Territories gazetteer were produced in 1971. The field-research program in Prince Edward Island was completed, and a revised list of ice features incorporating 223 additions and corrections to *Special Supplement No. 1-A List of Glaciological Features in Canada* was prepared.

The Book Library and Map Library both continued their service to the Branch. They also continued to provide other government agencies and the general public with surveying and mapping information.

Branch Publications Unit

During the fiscal year under review, the Publications Unit edited and produced publications in topography, photogrammetry, geodesy, cartography and geography.

The publication output consisted of 10 technical reports; 10 reprints from professional journals, the originating authors being members of the Branch; 9 issues of the

monthly in-house publication *The Surveys and Mapping News;* 4 special reports authored by consultants to the Branch; 1 seminar proceedings from the University of New Brunswick; 3 workshop study reports authored by members of technical workshops held in the Branch; and the production and editing of 3 technical papers for presentation at Branch technical seminars.

Map Distribution Office

The Map Distribution Office continued its normal work of issuing maps, charts and flight-information documents to government departments and selling them to the general public. An interesting comparison between the year of this report and five years ago is given in the following table:

	1965-66	*1970-71*
Total distribution of maps and charts	3,200,000	3,344,000
Sales to the public	820,000	1,828,000
Revenue from sales	$260,000	$539,000
Total orders filled	54,000	84,000
Sheets received from presses	14,500,000	18,700,000
Subscribers to *Canada Air Pilot*	6,800	9,600
Subscribers to *Enroute Charts*	4,100	5,800
Dealerships in operation		
Map dealers	175	345
Air-chart dealers	150	246

SPECIAL BRANCH FUNCTIONS

Foreign Aid Activities

The Canadian International Development Agency (CIDA) has continued to call on the Surveys and Mapping Branch for assistance in evaluation of work done on capital projects abroad and for advice and assistance in meeting requests for training.

Work on two projects, a *Land Valuation Index* for Barbados and semi-controlled mosaics for part of the coastal area of Kenya, was completed during the year. Further progress was made in topographical mapping projects in Tanzania, Kenya, Guyana and Trinidad and Tobago. A feasibility study for a project proposed for Ghana was also undertaken and completed.

Familiarization tours and on-the-job technician training have been provided for survey staff from Guyana, Morocco, Ceylon, Kenya, Jamaica and India during the year. A twelve-week summer course was provided for 24 undergraduate students from 8 different countries attending Canadian institutes of technology and universities under the sponsorship of CIDA and five others were attached to the Branch to gain experience during the summer months.

International Boundary Commission

The Commission continued the annual field maintenance required for the effective definition and marking of the 5,525 miles of boundary dividing Canada and the United States. Inspections were carried out on various parts of the line, and maintenance operations were undertaken in three areas by the Canadian Section of the Commission.

The Commissioners for Canada and the United States made joint inspections along the line and inspected the work of field parties on the boundary between Manitoba and North Dakota, Quebec and New York, and Quebec and Vermont. The Commissioners, together with federal and provincial dignitaries, attended a ceremony to unveil a plaque commemorating the establishment of a monument on the international boundary marking the completion of the survey of the Manitoba-Saskatchewan boundary in Manitoba's Centennial Year.

A Canadian field party working on the Manitoba section of the international boundary erected the above-noted commemorative monument, inspected 92 additional monuments, 17 of which required repairs, and treated with herbicides 89 miles of 20-foot boundary vista.

A second Canadian field party, working on the Ontario-Minnesota boundary, continued resurvey operations along the Rainy River, to re-establish many reference monuments lost through erosion, and to improve the overall accuracy of the original boundary survey in that area. Later in the season this field party transferred to the Quebec-Vermont boundary where a similar resurvey operation was initiated to replace and repair damaged monuments and to improve the geographic data on boundary monuments, which are presently based on surveys completed in 1907.

In addition, field officers of the Canadian Section completed the annual position checks on buoys defining the international boundary through the fishing grounds at the western end of Lake Erie.

INTERDEPARTMENTAL COMMITTEE ON AIR SURVEYS

In 1970 a modern jet aircraft was used for the first time on ICAS photo contracts. Approximately 34,500 line-miles of high-altitude photography were obtained in areas stretching from northern Ontario to British Columbia by a Lear Jet Model 24. At the same time, conventional aircraft equipped with super-wide-angle-lens cameras were photographing the entire wheat-growing area of the Prairie Provinces, in co-operation with the provincial governments, on the LIFT program.

As a result of these activities, 1970 was a banner year for ICAS photography—492 rolls of black-and-white photography (64,323 negatives) and 30 color rolls (3,500 negatives) were obtained.

GEOLOGICAL SURVEY OF CANADA

The Geological Survey carries out mapping, detection, interpretation, research and advice in the earth sciences and co-ordinates these to provide a national and regional inventory of formations of rocks and surficial materials, their structures, minerals, landforms, and conditions of stability. It develops concepts and techniques to maintain the standard of the inventory and to increase its usefulness and effectiveness.

To meet these objectives the activities of the Branch are carried out by six divisions, one of which is the Institute of Sedimentary and Petroleum Geology in Calgary, and by centralized support services. During the report period the Branch had 473 active scientific projects, of which 174 involved field studies. Most field projects were directed by permanent staff members, although some were led by university professors or postdoctoral fellows. Some studies, especially the federal-provincial aeromagnetic surveys, were carried out under contract.

MINERAL AND ENERGY RESOURCES

Many of the Branch's activities contribute to the goal of estimating the potential abundance and probable distribution of unfound mineral and fuel resources in Canada both regionally and nationally. This includes a complete inventory of the geology of the crustal rocks of Canada leading to an understanding of the sequence of geological events and the processes giving rise to their formation and subsequent alteration, and of the related mineral and fuel deposits that they contain.

This is accomplished by:

a) providing the necessary systematic geological framework to consistent standards as the essential basis for resource estimates; it is derived from various geoscience surveys on land, from the air, from ships, and by employing subsurface information;

b) establishing the geological settings favorable to the occurrence of various types of mineral commodities and fuels resulting from mineral-resource and petroleum-geology studies;

c) identifying such favorable settings within the geological framework and thus delineating potential ground for mineral deposits and for pools and deposits of fuel resources; these are derived from results of geoscience surveys, metallogenic (conceptual) appraisals, and statistical probabilities of the potential abundance and probable distribution of mineral and fuel resources;

d) studies of regional parameters to provide greater consistency of nomenclature and correlation and a deeper understanding of the geological framework than by the systematic surveys;

e) back-up of the above systematic studies by special investigations devoted to: paleontological, radiometric, and paleomagnetic chronology, correlation, and calibration of rock units; the establishment of standards and reference material in respect to analyses, mineral and rock composition, and fossils; specific geological processes and relationships of concern to systematic mapping and resource studies; and pilot projects to test concepts and methods before applying them in a systematic way.

The Geological Survey is close to attaining one of its long-term goals, that of providing the initial complete bedrock geological map-coverage of Canada at a minimum scale of 1:25,000, an effort that will be completed by about 1976. Operation Penny Highlands, carried out in central Baffin Island, the last major unmapped area in Canada, resulted in the mapping of 54,000 square miles of

Precambrian rocks. Two Bell helicopters were used for traversing and an Otter aircraft equipped with oversize wheels was used for support service. All field observations were recorded on forms prepared to facilitate the computer handling of the data.

As part of the national reconnaissance and in response to interest shown by the petroleum industry an aircraft-supported project was carried out to improve our knowledge of the stratigraphy of Prince of Wales Island in the central Arctic. Traversing was by means of a Bell helicopter and a Piper Super Cub equipped with oversized tires, and about 570 landings were made at sites where critical data were required.

A regional geological study of the lower Mackenzie River area was begun in 1968 and completed in 1970. This project combined reconnaissance bedrock mapping, stratigraphic studies and investigation of surficial deposits. In all the area covered was 145,000 square miles, most of which was done in the first two years. Eight preliminary maps portraying the bedrock geology were released during 1970-71. The area examined in 1970 was limited to the Mackenzie Mountains, but the results obtained proved valuable to petroleum exploration being conducted to the northeast.

Several inventory-mapping projects were continued in the Cordilleran Region in order to up-date older reconnaissance studies. Operation Stewart, in the region of the Yukon-District of Mackenzie border was completed, as was Operation Finlay in north-central British Columbia. Similar mapping was commenced in the Snag area of the Yukon, where many parts of the area were explored with the use of rubber boats powered by 33 h.p. motors. The study will be completed in 1971 with helicopters to reach otherwise inaccessible areas.

In the District of Keewatin west of Hudson Bay 1:1,000,000 reconnaissance studies made in the 1950s have been followed in the past few years by more detailed mapping, commonly at a scale of 1:250,000, and by more specialized studies. Last summer a detailed study of the Daly Bay anorthosite complex was begun in order to provide an understanding of the origin, age, and stratigraphic relationships within the body. To the southwest a study of the volcanic stratigraphy and metallogeny of the Kaminak Group of Precambrian rocks was begun. These rocks are similar to volcanic-sedimentary successions in the Superior Province, that part of the Canadian Shield which extends in a horseshoe-shape around Hudson Bay from near Churchill to Ungava Bay. The similarities include the great thicknesses, wide variety and extreme differentiation of the lavas, the presence of iron-formation, the many showings of base metals and precious metals and the complex geological structures. This study strongly suggests that the area, like the analogous parts of the Superior Province, has a high economic mineral potential.

In order to determine the effectiveness of regional geochemical methods, particularly hydrogeochemistry, a study was made in the Kaminak Lake area which, as noted above, has been examined not only on the broad 1:1,000,000 reconnaissance scale but where 1:250,000 mapping has been recently completed. Detailed studies were carried out to examine geochemical dispersion haloes near known metal occurrences. The results, both positive and negative, will be most useful in fulfilling the Survey's responsibility of providing better means of searching for and exploring mineral deposits.

The foregoing provides merely a sample of the Survey's activities that were directed towards the objectives of the Departmental Mineral and Energy Resource Program. Similar inventory mapping activities were carried out from the Strait of Belle Isle, New Brunswick, and Lake Superior to Manitoba and the Interior Plains.

Geophysical and geochemical surveys, a few of which have been noted, were also carried out in widely separated parts of the nation. Most of these activities are undertaken to support the more basic studies and include the development of concepts, criteria, methods, instruments and systems applicable to geology, geochemistry and geophysics and include the federal-provincial national aeromagnetic surveys. This project, started in 1962, was designed to cover those parts of the Canadian Shield not previously surveyed. Since then more than 1.3 million square miles have been mapped, 140,000 being completed in 1970. Maps on a scale of one inch to one mile are the usual method of releasing the data, and these maps now number in the thousands.

EARTH SCIENCES

Under this heading the Geological Survey provides a standard or primary surficial-geomorphology coverage of Canada. As in the Mineral and Energy Resource field this is accomplished by obtaining data, in part for the preparation of 1:250,000 maps. In local, selected areas such coverage is provided in more detail (scale 1:50,000) whereas in remote areas, such as certain regions of the Arctic where information is needed rapidly, preliminary reconnaissance surveys are undertaken in advance of systematic coverage.

The Geological Survey also provides information on the use and hazards of surface and near-surface materials and the dynamics and stability of terrain as it concerns its use by man. Several types of investigations are carried out, including the following:

1) The provision of pertinent information on the surficial geology of specific areas, e.g. the environmental geology of urban areas or the distribution of specific geological materials that have special significance for man's activities on the terrain.

2) Selected investigations concerning the physical and chemical properties of rock and earth materials relating to their use as foundations, sources of usable commodities, tracers, sources of contamination, sources of water, media for transmitting or impounding fluids, and media for disposal of wastes.

3) Studies in selected areas, concerning stability relations of rock and earth materials, sedimentation and erosion, slope stability or movement, and permafrost and ground ice.

4) The study of case histories of geologic-geomorphic aspects of terrain performance or terrain "failures" following land use or resource development.

These studies permit:

5) Prediction and assessment of natural hazards as well as man-induced hazards or pollution.

6) The preparation of land-capability or performance inventories for selected areas.

These investigations are nourished by special studies to provide basic information on terrain processes, mechanics of origin, and on stability and dynamics of various types of terrain, and to devise methods of field and laboratory investigations.

In November 1970, a flume facility enabling a wide variety of sedimentary environments to be studied experimentally was completed for the Geological Survey of Canada. The flume is of the tiltable, recirculating type with a channel 18.3 metres in length. Although primarily suited for studies of stream sedimentation and erosion, it can be readily adapted to the study of certain problems of beach and lake sedimentation and erosion. Controllable discharge, slope depth, and sediment characteristics provide a high degree of flexibility in the application of the flume to numerous environmental problems involving erosion and deposition.

During the 1970 field season inventory mapping of surficial deposits was carried out in many parts of Canada. In the Arctic a study of the glacial geology and geomorphology of southern Ellesmere Island and Devon Island was continued, and similar studies were undertaken on Herschel Island, Yukon, and on the Mackenzie Delta and Arctic Coastal Plain. Studies in the latter areas will be considerably increased in 1971 in support of a study of the Mackenzie Valley Transportation Corridor. Similar studies were made in more settled parts of Canada, including southern Labrador, southwest Cape Breton Island, Kingston and Arnprior areas of Ontario, Winnipeg map-area and the Assiniboine River valley of Manitoba, the South Saskatchewan River area, and in several map-areas in southern and central British Columbia.

In conjunction with studies directed toward the search for mineral deposits a project designed to sample surficial materials was carried out in the Kaminak Lake area of the District of Keewatin. Samples of glacial till, marine sediments and esker sediments were collected on a predetermined grid pattern for analysis to determine the dispersal patterns caused by glacier transport of mineral and rock fragments and trace elements from their source areas. Sample sites were reached by helicopter and at each site a pit 20 to 30 inches deep was dug from which the samples were selected. As many as 45 were collected each day.

The increasing expansion of Canadian cities has focussed attention on the need for land-use planning as a basis for orderly and efficient development of urban-centred regions. Geoscience data are significant components of the information needed by planners, developers and administrators concerned with multiple land use. Such studies could be classed as "environmental geology" and include management of land resources, water resources and subsurface fluids, waste disposal and usable rock and mineral materials (E.G. sand and gravel). In view of the increasing need for this type of information the Geological Survey undertook a prototype study of a 3,000-square-mile area to develop methods of compiling, evaluating and presenting the required data. During the 1970 field season data from 3,100 boreholes were compiled from existing sources and were coded in a form suitable for a computer program, from which it is expected that maps displaying the data can be produced. Surficial mapping at a scale of 1:50,000 was carried out in parts of the area. The engineering-geological characteristics of bedrock material were examined in order to assess the influence of bedrock topography on future land use, the effects of bedrock characteristics on foundations, the excavation characteristics of various rock types.

DEVELOPMENTAL ACTIVITIES

In support of its main objectives in the fields of mineral and energy resources and earth sciences, the Geological Survey seeks to improve the methods whereby data are acquired, to develop new concepts and instrumentation, and to establish physical, chemical and paleontological standards.

In geophysics, development continued on airborne gamma spectrometry, and two experimental area surveys were undertaken. The results of this work, reported in *GSC Paper 71-1, Part A,* showed that the technique is successful, and they also disclosed several prominent radiometric anomalies similar to those that are associated with known uranium areas such as Elliot Lake, Bancroft, Uranium City or Wollaston Lake. It appears that these new areas have a better-than-average potential for radioactive mineral deposits.

Seismic-survey techniques were also used in support of many projects in order to obtain strata thicknesses. Such studies were carried out in eastern Ontario, along the Toronto waterfront, along the route of the new Welland Canal channel, and in the Beaufort Sea north of the mouth of the Mackenzie River, where both reflection and refraction techniques were tested in an attempt to define the base of the permafrost.

The Geological Survey continued to be in the forefront of the development of geochemical exploration methods, and a major achievement was the successful application of these techniques in areas of permafrost by using surficial materials as the sample media. A field project in the Coppermine area demonstrated that these techniques have a real potential as an exploration tool, and the data collected lend themselves to presentation by computer-produced maps.

Standards of time and stratigraphic sequence are necessary for proper correlation of geological events. Dating of rocks is achieved by physical and paleontological methods. During the report period 182 K/Ar age determinations were made, as were smaller numbers of Rb/Sr and U/Th/Pb age determinations. A new 15-inch solid-source mass spectrometer, completed and tested during the year, will be used mainly for high-accuracy lead and uranium isotopic analysis. Radiocarbon dating is used for organically-derived materials dated in thousands rather than millions of years. A total of 224 determinations were made, mostly to support Survey studies, but some for the National Museum of Man to date archeological sites. Many thousand of fossils were identified, both from collections made in the field and from well-core samples. All these "dating services" greatly facilitated the studies carried out by the Survey.

GENERAL

In order to make the results of its studies available to government, industry and the general public, the Branch, supported by Public Relations and Information Services, has an extensive publication program. During the year 1 memoir, 7 bulletins, 3 economic geology reports, and 60 preliminary papers were published, and 30 manuscripts were made available to the public by means of Open File reports. The most significant item published during 1970-71 was the 5th edition of the book *Geology and Economic Minerals of Canada,* an 838-page text accompanied by a folio of 8 multicolored maps and correlation charts illustrating all aspects of Canadian geology. In addition, 354 new aeromagnetic maps were released and, in order to keep older information readily available, 24 publications were reprinted, as were 205 aeromagnetic maps. In addition to these publications members of the staff published 166 papers in outside journals, gave 108 presentations to scientific meetings and delivered 85 university lectures.

To stimulate research in the solid-earth sciences at Canadian universities the Geological Survey, on the advice of the National Advisory Committee on Research in the Geological Sciences, awarded $228,000 in general grants-in-aid during the report period.

Earth science is demonstrably valuable to Canada's national wellbeing. Since much non-renewable resource information is gained by commercial corporations based and controlled outside of the country in competitive situations requiring security of information, it is essential that the Government of Canada be provided with its own cadre of experts in order that our resources be effectively managed. This the Geological Survey endeavors to do. The results of the year 1970-71 amply illustrate how this requirement was met.

MINES BRANCH

PHYSICAL METALLURGY

During the period of this report, the Physical Metallurgy Division conducted research and development work in support of the Mines Branch activities on minerals and metals technology, and environmental improvement. The major portion of this work is related to the conservation, processing, properties, and utilization of Canada's metals, and the fabrication of products from these metals. The Division also undertakes work for the Departments of National Defence, Public Works, and Transport.

Research activities are based on an assessment of present and future requirements for continued technological growth. Emphasis is on applied research and development that needs pilot-plant-scale melting, casting, and fabricating facilities, to provide the maximum assistance possible to the Canadian economy in general, and to the metallurgical and resource industries in particular.

The applied research of the Physical Metallurgy Division covers three activities of the Mines Branch. These are: pollution abatement, processing of metals and alloys, and the evaluation and improvement of metals and alloys. The Division also carried out a number of special investigations for other government departments.

Pollution Abatement

The problem of air pollution by the Canadian iron and steel industry is of vital importance. A report entitled *A Canadian View of Steelmaking Air Pollution* has been prepared to serve as a basis for evaluation of the feasibility and suitability of studies of pollution abatement in the iron and steel industry that might be initiated within the Division.

Processing of Metals and Alloys

The purpose of this activity is to further technological development in converting Canada's mineral resources into useful metal products, in order to meet the changing needs of industry and the Canadian economy. Processing operations such as melting, casting, forging, rolling, welding, and powder metallurgy are studied under this head.

The Leigh Oxygen Probe System, which was developed in these laboratories, is being used to study soluble oxygen contents in basic electric steel, to relate the soluble oxygen content of rimming steel to ingot structure, and to study the deoxidation reactions under conditions similar to those existing in commercial steel plants.

Research is being carried out in specific areas of foundry technology dealing with the flow of metals in moulds, moulding materials and specialized moulding and casting techniques.

X-ray television fluoroscopy is being used to study the manner in which molten metal enters a mould cavity. These studies have shown that complete filling of a sprue does not occur unless the dimensions are somewhat less than those predicted by present theories.

Studies on melting and solidification deal with phenomena occurring in the melt and in the solidification of metals, which influence the quality and characteristics of the solid product.

The form and distribution of graphite in cast irons have a major influence on their properties. Work on the malleableizing process for white cast iron has indicated that the nuclei of the graphite particles are formed during solidification, rather than on subsequent heating. Graphite formation in thick-section nodular cast iron is adversely affected by small amounts of lead, antimony and bismuth. An investigation of this problem is in progress.

The characteristics of the particles of metal powders vary with the process by which the powders are made. The type of powder also influences the processing and quality of the powder-metallurgical product. Nickel and iron powders from various Canadian manufacturers are being studied to determine the particle characteristics and their influence on production processes.

Research is in progress to study the heat-affected zone-cracking tendencies of welds in structural steels. The validity of using fillet-welded assemblies to evaluate heat-affected zone cracking in butt-welded joints is being examined. The notch ductility of the welded joints produced in a shipyard by five different welding processes, using CSA G40.8 Grade B steel, is being examined in order to provide data useful to the Canadian Armed Forces in selecting welding processes for shipbuilding. It has been shown that the properties of the welds differ significantly with the welding process used.

Research is being conducted, in co-operation with the galvanizing research sub-committee of the Canadian Lead-Zinc Research Committee, to study the reaction kinetics of the iron-zinc system, in order to obtain basic information on the rate laws governing the reaction and to indicate methods by which galvanized-coating formation and properties can be improved and controlled. A group of steels containing silicon is being examined over a range of galvanizing temperatures and steel pretreatment conditions. Silicon-containing steels are normally difficult to galvanize.

Evaluation and Improvement of Metals and Alloys

The work in this field is concerned with understanding relationships between properties and composition so that the usefulness of metals and alloys can be established. This work is designed to meet the future potential needs of the Canadian economy and defence needs for new and improved alloys suitable for use in our environment, and adapted to the most effective utilization of our mineral resources.

A study is being conducted of the relationship between the mechanics of brittle fracture and ductile fracture in high-strength alloys. An extensive fractographic investigation of the environmental cracking of 18% Ni maraging steel in 3.5% NaCl solution has been completed. Significant variations in fractographic appearance have been observed which can be correlated with stress-corrosion or hydrogen-embrittlement cracking.

Knowledge of the dynamic fracture toughness of structural steels and the effect of thickness on this property is important in a number of applications, especially in the Arctic. Research to date has concentrated on the development and refinement of experimental techniques required in this research.

The effect of variations in rolling conditions on the strength, toughness and microstructure of G40.8 Grade B steel has been determined. The effect of rolling temperature and pass reductions on the loads imposed on the rolling mill is also being studied.

The influence of aluminum, nitrogen, sulphur and silicon within normal composition ranges upon the susceptibility to hot and cold cracking of welds made in a carbon-manganese structural steel is being investigated. Work to date has indicated that there is a critical range of aluminum content for which hot ductility about 1090°C (2000 °F) is considerably reduced, thereby increasing the susceptibility to hot cracking on welding.

A joint project is being carried out in co-operation with Endako Mines Ltd., Vancouver, B.C., to develop a new chromium-nickel-molybdenum stainless steel. Three of the experimental alloys produced are being field-tested as fine wire mesh in a papermaking environment.

Research on stainless maraging steels has demonstrated that beryllium can be substituted for titanium as the age-hardening constituent, and that the optimum chromium and nickel content in this class of alloy would appear to be 12% Cr and 8% Ni.

Titanium alloys are attractive as structural materials because of their low densities and high potential strengths; the strongest of them, however, suffer from low ductility. Alloys suitable for structural purposes are being evaluated to determine both their susceptibility to environmental cracking and weldability. The problem of low ductility of high-strength alloys containing more than 13 at .% Al is being investigated, and hardening mechanisms in a high-strength Ti- 45% V- 2% Si alloy are being studied.

A detailed study of the aging mechanisms in the commercial magnesium alloys Mg-9Al-Zn and Mg-Nd-Ag-Zr is being made to help determine the optimum properties for these alloys.

Special Projects

The following items are typical examples of investigations that have been undertaken during the past year in response to specific requests.

As a result of their investigations, scientists of this Division were able to reconstruct the sequence of events that led up to the major explosion on HMCS *Kootenay,* and were therefore able to identify the cause of this disaster.

The Physical Metallurgy Division acts as examining authority for the certification of personnel for nondestructive testing on behalf of the Canadian Government Specification Board (CGSB). Since the initiation of the program ten years ago, 1,797 radiographic and ultrasonic test personnel have been examined, and about 86 per cent of these were certified.

In the Defence Research Board research vessel *Quest* the inside surface of the steel fuel ballast tanks is partly lined with acoustic tile having a high graphite content. The

remaining steel surfaces are coated with an inorganic zinc paint. The tanks usually contain a seawater layer beneath an upper fuel layer. It was requested that the likelihood of corrosion be investigated. Laboratory tests indicated that such corrosion was not likely.

Reports, Investigation and Requests for Information

The Division issued 177 reports during the period under review. This includes reports and publications on research, reports on technical visits and committee work, and reports on investigations.

In addition to these services, the Division also dealt with 245 requests for information and advice that could usually be answered by letter; 117 such inquiries came from 87 Canadian companies and 128 originated with 25 government agencies.

FUELS RESEARCH

The decline in the rates of production of natural gas and petroleum in the United States in the face of growing demand is a matter of growing concern, and has made governments around the world more conscious of the role played by energy in sustaining a reasonable standard of living. Canada is no exception, and the Fuels Research Centre, which is the agency of the federal government responsible for evaluating the quality of the fossil fuel resources and for developing new engineering and scientific approaches to encourage their efficient utilization, has had to accelerate its resource-evaluation work.

To concentrate the activities of the Fuels Research Centre on major national needs in a manner that would permit better financial support and control under the Department's Mineral and Energy Resources Program, the research work is conducted under two heads: (1) energy and (2) environmental improvement.

The relocation and reconstruction of facilities of the Fuels Research Centre at the new site near Bells Corners, Ontario, 12 miles from Ottawa was completed with the construction of the diesel-engine testing facility of the Canadian Explosive Atmospheres Laboratory. This relocation of the Centre, though expensive and time-consuming, has led to improved operations.

Under the energy program, plans were made by the Department in the spring of 1971 to support a joint drilling program with the Province of Saskatchewan to determine the amount of lignite available for potential use as a source of thermal power. It was recognized that it was not known to what extent it was possible to differentiate leonardite from lignite by conventional geophysical methods. As the calorific values of these two minerals differ widely, a program was initiated to drill and core some exploratory holes in areas where these minerals were known to occur. The analysis of these cores and the associated log data will provide a basis for planning the large-scale drilling program which was to begin May 1, 1972.

Measures to improve the quality of the environment may be divided into projects concerned with (1) the improvement of combustion processes and the elimination of pollutants after combustion by dispersion into the atmosphere; and (2) the elimination of sulphur from the fuel and the improvement of fuel quality before combustion.

As a result of aerial surveys of Boundary Dam, Saskatchewan, and at McMurray, Alberta, significant progress was made in the development of improved techniques for aerial probing of hot smoke plumes from tall chimneys. This had led to a better understanding of the dispersion phenomenon and the capacity of air sheds to absorb pollutants. A consequence of this work will be a much-improved basis for the design of chimneys to protect ambient air quality and to give an indication of the levels of industrialization that are possible with existing technology.

The efforts made to develop a satisfactory thermal method for the destruction of liquid DDT has culminated in the construction of a $150,000 incinerator by the Defence Research Board at Suffield, Alberta, based on the design developed in the Canadian Combustion Research Laboratory. Further research has led to the development of equipment for the thermal destruction of DDT in powder form. Technical bulletins describing the research on both liquid and powder DDT have been published.

The growing need for information on the incineration of municipal waste has been met by publishing a bulletin describing a variety of commercially available equipment, including many of the technical factors that must be considered in the selection of the most suitable equipment.

An efficient route to thermo-electric power from fossil fuels without air pollution, requiring a minimum of coal preparation and capital investment and yet possessing excellent turn-down capability, is through gasification followed by combustion and subsequent conversion of the

heat to electric power through steam and gas turbines. Calculations are in progress to find the areas in Canada where such advanced technology might be applied.

It is inefficient to attempt to desulphurize the combustion gases arising from domestic heating and automotive and diesel transport. The sulphur must be eliminated prior to combustion. As the high-grade low-sulphur crude oils are gradually being consumed, it becomes increasingly important to devise inexpensive ways of refining low-grade high-sulphur crude oils. During the year the Mines Branch studied intensively thermal hydrogenation and catalytic hydrogenation in the liquid phase to determine the savings that could be achieved as compared with the conventional coking process. It has been shown that substantial savings through increased liquid yields can be realized.

To provide a more convenient reference for Canadian pollution studies, a listing of the sulphur content of Canadian crude oils in ascending order has been prepared. This listing makes the data in the Canadian oil-analysis directory more accessible and easier to use for this purpose.

The development of more powerful analytical tools plays an important role in petroleum research, and the benefits are felt in a wide variety of problems, from evaluating the quality of the crude oil resources to the identification of marine oil spills. In this connection new chromatographic columns employing lithium chloride supported on diatomaceous earth were found to separate the sulphur-containing compounds with high resolution at relatively low temperatures. The performance of these columns has been carefully studied by measuring the retention times of pure organic compounds containing a variety of sulphur linkages. This work gives every indication of living up to its promise of providing an excellent means of fingerprinting petroleum. The interest shown in this research and the financial support given to this program by the Department of the Environment are gratefully acknowledged.

A concern of the western Canadian coking-coal industry is the loss of coking properties that occurs through oxidation. This could occur through the oxidizing action of ground water on coal and exposure to air during mining, processing, transportation and storage. The study of this oxidation process is undertaken in order to design chemical methods of preventing or slowing down oxidation. The indications from the work of the past year are that coals differ considerably in their oxidation behavior but that in certain coals functional groups are formed which undergo condensation reactions on heating. The bonds formed as the result of this reaction prevent the coal from melting and forming strong coke.

Progress was made during the year on the development of a method for examining the maceral composition of fine coal. This advance promises to be very useful in studying coal when ground to the fine sizes required in pipelines, and for pyrite removal by electrostatic methods.

The Canadian Explosive Atmospheres Laboratory, the agency responsible for the certification of electrical equipment in mines where combustible gas mixtures may exist, expanded its facilities during the year through the construction of the diesel investigation facility. This specialized laboratory was established to improve the measurement of the exhaust emissions from diesel-powered mining equipment and safety with regard to explosion hazards. The official end of the construction stage of the laboratory was November of 1971, and it was expected that the remaining instrumentation would be completed early in 1972.

Research by the laboratory during the year covered the physical effects on the enclosure walls by short pulses of high pressure, and the correlation between plasma density and propensity to arc between electrodes. The increasing demands placed upon the certification service by industry have made it difficult to keep the research abreast of the need for basic information that is required to make certification judgments.

MINING RESEARCH

The Mining Research Centre has staff and facilities located at Ottawa, Elliot Lake and Calgary. More staff is now located outside Ottawa, at the Elliot Lake Laboratory and the Western Office, than in Ottawa at the Canadian Explosives Research Laboratory and the Rock Mechanics Laboratory. However, the actual work, which is done substantially in co-operation with mining companies, is spread throughout the country. The Western Office will make it easier to work with the western coal, base-metals and potash mines.

The Centre operates on the project system, many individual projects being integrated with the work of individual companies and universities. Wherever possible the prospect of an attractive payoff is used in the selection of projects. Those projects on which the potential benefit-cost ratio is particularly high receive maximum concentration of the budgetary resources.

Rock Breakage

The breaking of rock both at the mining face and subsequently in reducing the large blocks of ore to a fine size suitable for processing is a major part of mining. One objective is to explore the mechanics of breakage using forms of energy other than explosives that may lead to radically new mining methods. This is a pioneering activity undertaken at the request of the Mining Association of Canada as a result of a survey showing that its members believe rock breakage is one of the most important areas in which research should be able to effect savings.

Beside helping to increase efficiencies in current systems through the discovery of novel methods of drilling, blasting, crushing and grinding, it was also envisaged that conventional operations might be telescoped into some combined procedure quite unlike current practices. Simulation techniques using computers for the analysis and control of grinding circuits are also being developed. An investigation has been undertaken of the economic and technical feasibility of using modified wedging tools to remove rock as part of a tunnelling machine.

Blasting research is also being pursued to increase safety and to reduce the cost of drilling and blasting in industry, which accounts for the expenditure of approximately $130,000,000 per year in Canada. By the application of analytical techniques it should be possible to produce significant savings within a reasonable period of time. The resources of the Canadian Explosives Research Laboratory, the Rock Mechanics Laboratory and the Elliot Lake Laboratory, together with those of some private companies, are all being used for this work.

Ground Control

Canadian underground and open-pit mines will become deeper. The ground-control problems encountered at depth will be more severe than those presently existing. The present basis of engineering experience and trial-and-error procedures may not be sufficient to deal effectively with these problems. Consequently, a basis is required to aid judgment on what should be done once problems occur. The science of rock mechanics is not at the stage where mining excavations can be designed completely, and due to the complex nature of ground conditions rigid predetermined planning may not be feasible. At present, research provides relevant information to mine operators that assists them in making decisions regarding mining layouts, extraction, and artificial support systems.

With the increase of rock-mechanics activity in Canada the role of government mining research has changed. It is now developing comprehensive theories on rock deformation and failure; evaluating instrumentation suitable for Canadian mines; and dealing with projects which demand a multi-disciplined approach. At present these functions are beyond the scope of most mining companies. In addition, the engineers working at one mine are familiar mainly with conditions at their own mine, whereas government research scientists who visit and conduct projects at mines through Canada build up a broad backlog of experience. This experience is useful in providing advice on request to mining companies when ground-control problems occur.

Ground-control research is divided into basic and applied projects, and an even balance is sought between the two. Basic projects are oriented towards the simulation of geological and excavation conditions; providing basic information of mine rock; and evaluating rock-mechanics instrumentation. Applied projects are oriented towards solving typical problems in mines and deal with: roof stability in salt and coal strata; wall and pillar stability in hard-rock mines; the stability and the use of artificial support for open-pit slopes; and the problems of outbursts in coal mines.

Research is being carried out at three laboratories: the Rock Mechanics Laboratory, Ottawa, where mainly theoretical work is carried out; the Elliot Lake Laboratory, where applied research is done in the hard-rock and evaporite mines; and the new Western Office in Calgary, which is presently concerned with the problems in coal mines.

Environmental Control

Respirable dust has long been recognized as the cause of a pulmonary occupational disease called pneumoconiosis. In Canada modern mining methods have increased the amount of respirable dust produced in mines. Improved ventilation has countered the serious damage that would have occurred. Co-ordinated efforts of governments, universities and industry are required if the quality of the mine environment is to be improved and the respirable-dust problem eradicated.

The work in this area has been directed towards certain neglected areas of the physics of dust measurements, such as (1) the development of standard methods of measuring dust and radiation hazards; (2) the classification of mine environments in terms of dust hazards based on rock-dust relationships; and (3) more efficient ventilation.

The need for and the benefits derived from this program have been corroborated by industry. At the present time, research on the standardization of methods for measuring dust and radiation hazards are being conducted in close co-operation with the Mine Accident Prevention Associations of Ontario and Quebec as well as with individual companies experiencing critical problems. The payoff for this program will be realized if the increased knowledge results in reduced compensation payments and in safety codes that will safeguard the health of the miner with the minimum impedance to technological advances in production.

The work is being done primarily at Elliot Lake.

Mine Systems Engineering

Work has been started on systems analyses of various mining operations. Advances that are made by physical research on the various phases of operations (drilling and blasting, ground control, transportation, etc.) are being examined to determine their influences on mine economics. Computer programs are being developed for use by company staffs on mining properties.

With the high degree of complexity of current technology, we find that no organizations exist in the country with the personnel and facilities capable of assisting those with problems in many specialized areas. Consequently, calibration, testing and advisory services are provided when required by companies and agencies in the mineral and associated industries. This is consistent with the Mines Branch policy of orienting its research to fill gaps in technology of particular concern to the country. At present, most of the work is being performed at the Canadian Explosives Research Laboratory.

The general function of communication is being expanded by the development of an Information Centre involving both the Mines Branch Library and the Elliot Lake Laboratory. Through information officers and telex links it is planned to provide industry and the universities with assistance in obtaining the latest research information on any subject. At present, integration with private research is achieved either through joint projects or through liaison on subjects of mutual concern. The companies co-operating with the Mines Branch in research produce approximately 75 per cent of the Canadian mining output. Besides the conventional method of publishing significant results in journals, interim reports are written. Some of these are distributed exclusively through the Mining Association of Canada to interested companies, while others are used as research notes that are exchanged with laboratories both in Canada and abroad.

Canadian Advisory Committee on Rock Mechanics

In 1963, the Canadian Advisory Committee on Rock Mechanics was formed to stimulate greater interest in this base science for mining and to co-ordinate research. The membership has consisted primarily of representatives of industry and of the universities, with Mines Branch personnel providing the secretariat.

During the past year, one of the committee's specialist panels completed a study of the requirements for rock foundations. It is expected that new Canadian building standards will result from this study.

One of the principal ways in which the Mines Branch, with advice from the committee, has been able to stimulate research is through its grants-in-aid which, starting with $10,000 in 1962, have grown to a total of $363,000 for mining research. The committee also periodically examines and appraises the research of the centre in rock mechanics.

MINERAL SCIENCES

There has been a significant change in the direction of effort in the Mineral Sciences Division during the fiscal year 1970-71, and particularly during the latter part of that year. In order to bring the work of the Division more into line with current departmental objectives, materials research has been considerably curtailed and has been replaced by work in the environmental improvement field insofar as this relates to the mining and metallurgical industries, largely making use of equipment and expertise available in the Division. There has also been a significant expansion of the Division's effort in the field of standards of various types. Some of the more notable developments in the various programs are detailed below.

Sulphides

In the characterization of sulphide minerals, on which much of Canada's base-metal industry depends, studies of the crystallography of various types of pyrrhotite, chalcopyrite, cubanite and related minerals have been conducted. Subtle variations of composition and structure are thought to have a bearing on the ease or difficulty encountered in beneficiating ores containing these minerals. Several hitherto unknown variants have been isolated and characterized compositionally and crystallographically.

The work on the growth of synthetic sulphides and related compounds intended to simulate naturally occurring mineral species and to be used for various crystallographic and physical studies has been continued throughout the year, with a range of techniques.

Regional studies of mineralogically significant areas in Canada have been continued. The extensive studies of the silver deposits in the Cobalt-Gowganda area of northern Ontario, conducted over many years, have been brought to a successful culmination with a comprehensive and definitive publication of the findings. Studies are currently under way into the mineralogy of the porphyry copper-molybdenum deposits in the Highland Valley area of British Columbia, the base-metal deposits in the Red Lake area of northwestern Ontario, and the tungsten-tin deposits in southwestern New Brunswick.

Materials Research

As mentioned above, certain work in this field has been curtailed during the latter portion of the fiscal year 1970-71. This includes the series of high-temperature phase-equilibrium studies in multi-oxide systems conducted over many years, also the work on magnetic ceramic materials (ferrites). Both projects are being gradually terminated with the publication of the results. In the phase-equilibrium work, the systems CaO-Nb_2O_5-TiO_2-SiO_2, ZnO-Nb_2O_5-SiO_2 and CaO-Fe_2O_3-Al_2O_3-SiO_2 have been studied and significant advances made in our knowledge of these systems which have mineralogical and/or technological significance.

Studies of "hard" or permanent-magnet-type ferrites have been concluded with the publication of a series of papers dealing with the ceramic and magnetic properties of strontium, barium and lead hexaferrites. The study of "soft" or spinel-type ferrites, widely used in computer and magnetic-tape applications, have been continued with statistically-designed experiments. In the fabrication of these materials, the application of the freeze-drying technique has been found to be particularly applicable.

Analytical Research and Services

This program has led, during the past year, to several developments that are significant to the mining/metallurgical industries. Foremost among these is the increased involvement of the Division in the development of various types of standards—namely, standard methods of analysis and standard reference materials.

A project is under way to develop a group of standard reference ores of various types that are typical of mineral deposits in Canada. A co-operative analytical scheme, involving many outside as well as governmental laboratories, has been applied to these ores and the results assessed statistically. The ores can now be certified for several elements to within specified limits of accuracy, thus providing reference materials that can be used to monitor analytical procedures for these elements. The materials to which these procedures have been applied include platinum-bearing samples, such as a British Columbia alluvial sand, and a Sudbury copper-nickel matte; the work is being extended to include a Sudbury concentrate. A molybdenum ore from the province of Quebec, a complex W-Sn-Zn-Cu ore from New Brunswick and a Cu-Mo ore from British Columbia are also being investigated for similar purposes.

The Division continues to be heavily committed to the development of nationally and internationally acceptable standard methods of analysis for metallic constituents, on behalf of the Canadian Standards Association, the American Society for Testing and Materials and the International Organization for Standardization (ISO). Metallic standards for emission-spectrographic work are also under development. In all these aspects of standards work, the use of statistical procedures for evaluation of the results is increasing; such methods are also being used in assessing the techniques of sampling and of processing the ores.

The use of on-stream analysis of slurries is becoming increasingly significant in mineral beneficiation and processing. The Division is conducting studies involving the use of X-ray fluorescence in such work; in some instances the X-radiation is excited by employing radio-isotopes such as Cd-109. The technique of nuclear magnetic resonance spectroscopy is being adapted to estimate the water content of the slurry, thus providing a complementary means of analysis.

Environmental Improvement

As part of the Mines Branch program on this topic, the Division has recently undertaken a group of projects designed to improve the environmental aspects of mining and metallurgical operations. These include:

(i) A study of the various factors that affect the composition, in regard to pollutant elements, of the effluent waters from slag heaps, tailings piles and tailings ponds.

(ii) A study of open-layer silicate minerals (e.g. bentonite) that could be used as possible ion-exchange media for removing the pollutant elements from such effluents.

(iii) A phase-equilibrium study of the systems (Fe,Co,-Ni)-S-Cl, to provide information designed to be of use in devising alternate means of treating sulphide ores, thus eliminating the need for oxidative roasting, by attacking the ores with moist hydrochloric acid gas at elevated temperatures.

(iv) A comprehensive study of the methods available for the reduction of the SO_2-emission in stack gases from sulphur-bearing coal combustion or from sulphide-ore roasting operations.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, research and development were continued on hydrometallurgical processes, pollution abatement, and control of metal corrosion. Studies were also made of the kinetics and thermodynamics of various metallurgical reactions of importance in these fields. The results of the research were made available to the Canadian mining and metallurgical industry in Mines Branch reports and published papers, and through joint organizations such as the Canadian Mineral Processors, Canadian Mineral Analysts and the Canadian Uranium Producers' Metallurgical Committee, as well as through informal direct contacts.

Metals Extraction and Recovery

Over the past two years the leaching of uranium from coarse ore has been studied with the objective of developing a system of static leaching in mine stopes or in heaps above ground, utilizing bacterial action, to minimize mining and leach-plant costs. Pilot-plant tests on minus-8-inch Elliot Lake ore have indicated that an extraction of 85 per cent of the uranium may be obtained over a period of two years. More recently a co-operative study was carried out jointly by a Canadian uranium-mining company and the Mines Branch under actual mine conditions, and parallel results were obtained over a 30-week period. This investigation was terminated by suspension of mining operations, but it is clear that underground leaching of coarse uranium ore is a practical and effective way to treat some Canadian uranium ores.

One of the problems in using bacterial action to extract uranium from ores is that the resulting solutions contain much iron. A study was made on ion exchange as a method to recover uranium from such solutions. A weak-base anion-exchange resin with a very much higher selectivity for uranium than for ferric iron was found quite suitable for recovering uranium from liquor containing up to 10 g/l ferric iron. This technique overcomes the problems that have heretofore made the utilization of bacterial action for uranium extraction unattractive.

Solvent extraction can also be used to separate uranium from iron-containing solutions, and in this case the possibility exists of making the separation from a leach pulp, thus eliminating the filtering operation and reducing the treatment costs. The use of a sieve-plate pulsed column was investigated for this purpose, and it has been shown that 99 per cent of the uranium can be extracted with a loss of organic extractant of 0.13 lb/ton of dry feed. While this is an acceptable loss, work is under way to reduce it.

Solvent extraction has also been applied to the conventional ammoniacal pressurized leaching process for copper-nickel-cobalt ores. Here the conventional separation of nickel and cobalt is a rather complex operation. Using solvent extraction, clean separation of copper, nickel and cobalt can be achieved in rather simple ways. This work has been confirmed by two companies using their own solutions.

Environmental Improvement

Because of the problems of disposing of the sulphur dioxide generated in the conventional smelting processes for treating sulphide ores, a continuing search is being made for alternative hydrometallurgical routes that will be acceptable economically. For mixed sulphide concentrates of copper-nickel-cobalt, a pressurized leaching process, using either air or oxygen as the oxidant, is attractive, since this process is capable of converting much of the sulphur to the elemental form, which is non-polluting. Major problems to be overcome in utilizing this approach are the slow dissolution of copper that occurs when the copper mineral to be dissolved is chalcopyrite, and the extraction of dissolved copper from the iron-oxide residue. Work during the past year has shown that both these problems can be overcome, and there is now every reason to believe that this process can be made a commercial reality.

One of the minerals of perennial interest to Canadian metallurgists is the iron-sulphide pyrrhotite, because it is

of widespread occurrence and often associated with the valuable metals copper, nickel and cobalt, and because it contributes much of the sulphur dioxide generated in smelting processes. One process examined for treating it hydrometallurgically is hydrochloric-acid leaching. In this case the sulphur can be recovered in elemental form, the valuable metals can be isolated as high-grade concentrates, while the iron appears as a concentrated iron chloride, from which the hydrochloric acid can be regenerated.

Attractive as this process appears on paper, recovery of the hydrochloric acid is probably too expensive to make the process as a whole commercially attractive. However, a recent observation has suggested that if sulphuric acid is substituted for hydrochloric acid, the acid-recovery step can be simplified while retaining the attractive features of the hydrochloric acid approach.

While control of sulphur-dioxide emissions from plants treating sulphide ores and concentrates is certainly technically feasible in principle, a more difficult problem is presented by sulphur-dioxide emissions from the burning of coal and oil, partly because the gases are more dilute. While limestone has been extensively investigated as an agent for trapping sulphur dioxide, it has never been made efficient, and it also presents a solid-waste-disposal problem. Our work has shown that magnesium oxide supported with an iron-oxide catalyst can quantitatively absorb sulphur dioxide from dilute gas streams, and that the sulphur dioxide thus absorbed can be regenerated either as a concentrated gas for converting to sulphuric acid, or for reduction to elemental sulphur with coal, for example. As a result of the regeneration of the sulphur dioxide the magnesium oxide is also regenerated for reuse, thus eliminating the solids-disposal problem.

Although many metallurgical operations are free of problems associated with sulphur-dioxide production, all such operations cause water pollution. Many of these problems have been adequately dealt with over the years, but new and more stringent regulations are presenting operators with new challenges, as for example, controlling the emission of salts of copper, zinc and iron in liquids discharged from certain milling operations. The problem is complicated by the fact that the solutions are very dilute. However, it has now been shown that ion-exchange resins of the sulphonic-acid type can treat solutions of the kinds found in the Noranda and Sudbury mining areas, to yield final effluents that can be safely discharged into existing water courses.

Corrosion Prevention

Corrosion continues to be a significant cost factor in the mining and metallurgical industry. A survey of Canadian base-metal mines recently published by our staff showed that underground machinery and mill processing equipment commonly had inadequate protection. A number of test programs were initiated to try to reduce the effects of sulphur-dioxide gases and of acidic salts generated by the oxidation of sulphide-bearing dusts. New apparatus for simulating mill and plant atmospheres has been developed which makes it possible to accelerate testing of newly developed coatings to resist wet sulphur dioxide.

The formula of a conventional chemical conversion coating was successfully modified to include a novel accelerator, hexamine, and manganous acetate instead of manganous sulphate, to produce a coating impervious to a water-saturated sulphur dioxide. Studies were also made on conventional oxalate and phosphate conversion coatings to improve their resistance to mine and mill atmospheres. In addition, experiments were conducted in a grinding circuit to see if an economical corrosion-control method could be found to reduce ball and liner consumption. Results so far indicate that 20 per cent of ball and liner consumption is caused by corrosion.

The program on electroplating was continued in an attempt to find more effective and cheaper coatings for protection against salty atmospheres. A start was made on the development of non-porous electroplated coatings by studying the performance of thin chromium platings from our low-ratio plating baths containing sodium hydroxide. Increasing the sodium hydroxide content of the plating bath improved corrosion-protection capability of thin coatings by reducing the number of cracks and pits per unit area that occur in conventional platings.

Chemical Analysis

A large number of samples was analyzed for a wide variety of constituents in support of the Division's research. Advanced concepts in ore hydrometallurgy and enforcement of stricter pollution controls necessitated analytical research to modify existing procedures and to develop new procedures.

An investigation was made toward improving the procedures used in the atomic-absorption and flame-emission method for determining mercury in caustic cell sludges. One of the changes resulting from this study was the elimination of the oven-drying step in the conventional

analytical procedure, which was found to give erroneous results.

More accurate measurements on xanthates and dithiophosphates in flotation liquors of operating mills are required to control reagent consumption more effectively and to improve grade and recovery of sulphide concentrates. To meet these demands, work began on the application of the silver-sulphide membrane electrode for the continuous on-stream control of reagents employed in flotation processes. The experimental work to date has shown that both xanthates and dithiophosphates can be determined in the presence of other constituents in flotation liquors.

Arsine, evolved in the process to recover gold from arsenic-bearing cyanide solutions, is an extremely toxic gas which has caused some near-fatalities in two operating gold mills in Canada. In view of this situation, the problem of arsine evolution and the development of methods to prevent its formation were investigated. A substantial reduction in the amount of arsine formed can be achieved by either oxidizing the arsenic present in solution to arsenate with potassium permanganate, or by adding copper salts to render the metallic zinc inactive to the dissolved arsenic. Studies on the problem are continuing.

In anticipation of increased trade in uranium and its products between Canada and the United States in the near future, the analytical laboratories of this Division have been approved by the U.S. Atomic Energy Commission as an official umpire to represent Canadian interests.

METALS REDUCTION AND ENERGY

The Metals Reduction and Energy Centre completed its first full year of operation in fiscal 1970-71. The Centre was established to link research in pyrometallurgy with many of the activities in the metallurgical-coal and carbonization industries of Canada. Laboratories working at the pilot-plant scale are at two locations in the Ottawa area (Booth Street and Bells Corners) and in Edmonton, in space generously provided by the Research Council of Alberta at Clover Bar. The objectives of the Centre remain the same:

(a) To conduct studies of the energy requirement of the Canadian metals and minerals industries.

(b) To assess the related transportation problems in supplying these energy needs and in developing markets for metallurgical fuels and their products.

(c) To perform both research and development work up to the pilot scale:

- (i) on the production of "further-processed" metal ores (particularly reduced iron ores) ferro-alloys, and other metal products;
- (ii) on the application of energy to metallurgical processes, including fossil-fuels carbonization or conversion and metal-ore reduction; and
- (iii) the abatement of air pollution arising from some metallurgical processes, especially those of the ferro-alloy industry.

(d) To apply the results of these studies through:

- (i) organization of co-operative formal government-industry groups, such as the Canadian Carbonization Research Association;
- (ii) organization of ad hoc technical committees, such as that formed to study special problems in the hydraulic transport of coals to be used for coking;
- (iii) consultation with industry, universities and government representatives; and
- (iv) the preparation of reports and papers.

Pyrometallurgical Studies

The main effort of this group concerned electric-furnace production of ferro-alloys and related products. This industry is faced with a drastic need to reduce air pollution, since very fine dust is produced by the volatilization of charge constituents under the very high temperature of the electric arc. With reasonably priced electrical energy, Canada has always been in a favored position for the development of this industry. It is thus important to overcome these problems in such a way as to improve the economic position of this industry. Attention has been focused on furnaces producing silicon, and by year-end methods for markedly reducing dust formation while improving furnace performance had been devised. These techniques must now be assessed at the pilot-plant scale.

In another experimental study of air pollution in the pyrometallurgical industry conducted in co-operation with a leading non-ferrous metals producer, a pilot-scale program of volatilization of lead and other metals from flue dust was conducted. The object of this round-the-

clock investigation was to devise a method to allow recycling of these smelter waste products. Industrial application of this process awaits assessment of rival methods.

In support of studies being conducted by other industrial and research organizations, studies were undertaken on methods of pelletizing super-concentrates of an eastern Canadian iron ore as a first step in their application in one rotary kiln direct-reduction process. Promising results were obtained by blending and by choosing appropriate size ranges. Pelletizing studies were also conducted on a variety of minerals and waste materials to allow their use in subsequent processes.

An important aspect of this research is the development of instrumentation. Steady progress has been made on electric-data-acquisition equipment to improve control of the smelting furnaces and to reduce the time needed for the interpretation of the information obtained.

Coking-Coal Program and Related Studies

Severe disturbances occurred during the year in the supply of coking coal. This led to many demands on the Branch to assess the practicability of using new coals, particularly western Canadian coking coals, in the steel industry of central Canada. Accordingly in co-operation with the Department of Industry, Trade and Commerce, the Canadian Coal Producers, Transporters and Consumers Research and Development Group has agreed to discuss specific essential needs of the steel and coal industries and to make formal applications for research to the Program of the Advancement of Industrial Technology (PAIT). Two full meetings of this group were held in December 1970, and activities of this group were then co-ordinated with the current research of the Canadian Carbonization Research Association. The Department of Energy, Mines and Resources integrates the technologic aspects of its carbonization and related research with the latter organization to provide a good "coupling" with the needs of the industry and to provide an optimum use of the very restricted facilities available in Canada.

For the reasons noted above, carbonization research reached a new peak, with a total of 156 tests during the year. Efforts to relocate to the new Bells Corners site continued, and at year end only the twelve-inch movable-wall oven remained at the Booth Street site. This will be maintained in operation along with the two ovens at the new site (the new twelve-inch oven will begin operating early in the next year) until the demand for evaluation tests abates or until additional facilities are provided, possibly near the new western coal fields. In the meantime, work continues on methods of improving the technical performance of coke ovens by studies of pre-heating, use of additives, bulk-density control, etc., and improved evaluation methods with increased emphasis on petrography.

In the Western Regional Laboratory, great emphasis is placed on developing a method for the "re-constitution" of coking coal from hydraulic transmission slurries. A technically acceptable process was developed at the small pilot-plant scale. The development opens the way for the construction of pipelines to transport coking coal which hitherto had not been considered possible. A very considerable amount of coke testing in the Ottawa laboratories was needed to support this activity.

In addition to this major project, work continued on the long-range development of integrated coal-washing circuits applicable to the friable coals of western Canada; also a major project to upgrade lignite in full value to allow its more economic transport and to remove certain deleterious constituents has begun.

MINERAL PROCESSING

Research in the Mineral Processing Division has as its objective the most effective conversion and use of minerals. It comprises applied research in the fields of mineral separation, ceramics, construction materials and non-metallic minerals, and the provision of expert advice to other government departments and industry.

The Industrial Minerals Subdivision did research in mineral beneficiation, ceramics, construction materials, non-metallic minerals and waste minerals with support from the Ore Mineralogy Section. The work ranged from evaluation of mineral deposits, beneficiation and processing of industrial minerals to development of useful products such as ceramics, building materials, chemicals, fillers and composites. Some of the work was oriented largely toward materials science, where properties are determined and developed to ensure the most effective utilization of non-metallic materials.

The study of flotability of non-metallic minerals was continued by the Industrial Minerals Milling Section, and demand for additional published information on this subject was extensive. Photometric sorting was applied to the preconcentration of beryl, rare earths, and uranium. Work commenced on a project for separating sylvite from halite

by this method and on a method of comparing grindability of non-metallic ores. Mines Branch research on the flotation of celestite, a strontium mineral, helped the Kaiser Celestite Company plant in Nova Scotia to start operations. Investigations were carried out into beneficiation of Canadian ores of magnesite, beryl, feldspar, quartz, barite, spodumene, scheelite and marl.

The Construction Materials Section and the University of Ottawa started a joint project to determine the effect of below-freezing temperatures on the strength development of concrete. The durability of concrete under Canadian climatic conditions was tested in several projects. Investigations in the aggregate laboratory were made on the durability of both coarse and fine aggregate in exposed aggregate wall-panel units. Principal factors studied were effect of aggregate size, shape and grading characteristics on bonding stability with a cement matrix. This Section continued to co-operate with ASTM in developing strength-test methods, and it participated in a co-operative ASTM test series on the water requirements of different types of fly ashes in concrete mixes.

Studies were made by the Ceramic Section of the properties of new ceramic raw materials and products. High-purity alumina was prepared by a cryochemical method, and its thermal behavior was studied to provide background information on the problem of making Canadian alumina suitable for electronic substrates. A method of improving thermal-shock resistance of Canadian whiteware, stoneware, sewer pipe and flue liners was developed. The research involved the use of lithium compounds.

The preliminary apparatus was developed for the measurement of thermal diffusivity of solids based on theoretical models. Measurements performed on alumina and pyroceram specimens were in close agreement with accepted values, proving the soundness of the theoretical concept. Additional work is continuing on the development of this method.

The properties of minerals from many Canadian deposits were investigated. Clay and shale deposits were evaluated as potential sources of raw material for clay products and lightweight aggregates. Deposits of such materials as magnesite from British Columbia, talc from Ontario and British Columbia and Manitoba, limestone from Newfoundland, diatomite from New Brunswick, asbestos from Quebec, bentonite from Saskatchewan, gypsum, limestone and silica from Alberta were evaluated. Research on asbestos fibre was continued in co-operation with the Quebec Asbestos Mining Association. Work included study on the utilization of asbestos fibre for plastics, of dielectric-constant measurements as an indication of asbestos content and of the behavior of asbestos fibres in a magnetic field and the relationship between magnetic susceptibility and the magnetic content of asbestos.

Research was carried out in two general areas on metallic-ore concentration. Research on improved processes included projects on flotation and filtering.

Basic Principles of Flotation

Work continued on devising a method, based on photospectrometry, for determining and regulating the concentration of metallic ions in flotation pulp solutions. This is the principal means of developing the selectivity required to separate minerals of different metals, e.g. pyrite from chalcopyrite, sphalerite from pyrrhotite, lead carbonate from dolomite. Since copper-ion concentration is the critical determinant in the first two separations cited, work was concentrated on the complex copper-ion distributions in water.

A part of a flotation project to modify the structure of amine flotation collectors to obtain collectors specifically selective for "oxide"-type minerals has resulted in the synthesis of amine collectors that will float scheelite and lead carbonate cleanly from associated gangue minerals. A paper is being prepared for publication at the International Mineral Processing Congress, London, 1973.

Research is also continuing on a study of the electrical charges on the bubbles in the flotation process. The charge can now be measured and, if a method of controlling its sign and magnitude can be developed, it will be possible to increase the rate of flotation of very fine minerals liberated by the fine grinding required on ores such as those of New Brunswick.

Fundamentals of Filtering and Dewatering

Two plant research projects are in progress in co-operation with the Iron Ore Company and Hilton Iron Mines on the development of better filter cloths and faster filtration rates. Methods of evaluating filtration variables have been developed, including electron-microscope and streaming-potential methods.

In the second general area, the development of better methods of concentration of certain types of ores was the objective. The ores included molybdenum ores, mixed iron oxide-sulphide ores, low-grade nickel ores, tungsten ores, and a complex bismuth-tungsten-molybdenum ore.

Work was completed on a method for flotation of molybdenite ores from the Cadillac area of Quebec. These ores contain a high percentage of talc which has added greatly to operating costs in the past. A simple method was found to depress the talc and obtain a high recovery and grade of molybdenite. Unfortunately, the added problem of a depressed molybdenum market forced the two operating mines to suspend operations before the new process was ready for production trials. Its application will, therefore, have to wait for a more attractive economic situation.

Investigation of several low-grade nickel-sulphide ores has shown that the main problem in their concentration is the high percentage of nickel present as silicate minerals. The finely disseminated nickel sulphides can be liberated by fine grinding and flotation, but so far the nickel-containing silicates cannot be concentrated by physical methods.

As an assistance to new mine exploration, several investigations were carried out to define the concentration possibilities for the ores, so that their economic potential could be evaluated and feasibility of mining determined.

EARTH PHYSICS BRANCH

GRAVITY DIVISION

A major objective of the Division is to complete the regional gravity survey of the Canadian landmass, continental shelves and inland waters. The *Bouguer Gravity Anomaly Map of Canada* published in 1968 shows progress to the end of 1966. In 1971 as in past years efforts have been directed towards completing this program. Field surveys involving almost 7,000 new gravity stations have been made as follows:

1. A field party supported by two helicopters and one fixed-wing aircraft established 3,700 new gravity stations at intervals of eight miles in a large area of the District of Mackenzie and the District of Keewatin, including King William and Southampton Islands and the southern part of Boothia Peninsula.

2. Further to the north, on Banks Island, a small party supported by one helicopter established 910 new stations at eight-mile intervals throughout the island.

3. Approximately 1,500 new stations were observed at four-mile intervals on the sea ice of the Beaufort Sea. An additional 88 stations at seven-mile intervals were observed on ice immediately west of Banks Island. A major part of this survey was done in co-operation with hydrographers of the Polar Continental Shelf Project of EMR.

4. In British Columbia 167 new stations were observed on a four-mile grid adjacent to a proposed seismic experiment scheduled for 1973 in the Quesnel region.

5. Off the east coast of Canada 450 new underwater gravity stations were observed on a seven-mile grid on the Scotian Shelf. Gravity coverage in this area now extends for about 130 miles offshore and as far west as 65° 35′W.

6. A local gravity survey of the Guichon Batholith was made in co-operation with the British Columbia Department of Mines and Petroleum Resources and the University of British Columbia. About 200 stations at one-mile intervals were observed along three profiles. The results suggest a close relationship between minimum gravity values and porphyry-copper deposits.

These surveys have as usual been tied to the Primary Gravity Network of Canada. Publication of the new network has been delayed pending adoption of the International Gravity Standardization Network 1971 (IGSN71) to ensure that the new reference system for Canada will be consistent with world-wide standards. Adjustments necessary to achieve this are now in progress. The conversion from the present Potsdam standard to the new IGSN71 absolute values coupled with conversion to the new gravity reference ellipsoid (1967) involves a massive recomputation of all secondary control networks and gravity-anomaly data in the Division's file. This conversion will take about two or three years.

During the past year the Division has made a significant contribution to a special study group of the International Association of Geodesy responsible for establishing the IGSN71. Preliminary adjustments made by various participating agencies were in close agreement, and the final adjustment, involving 2,000 gravity stations around the world, was made in Ottawa with the Division's computing system. The new gravity-reference standard was adopted

in principle at the Moscow meeting of the International Union of Geodesy and Geophysics in August 1971.

In March of 1970, the Division's Datacentre installed an EAI 430 flatbed plotter. This machine has provided significant improvements in accuracy and performance over the previous plotter. A general software package has now been developed for use with IBM 360 FORTRAN IV programs, and development is continuing on an automated contouring package. In August 1971, the Department announced the acquisition of a CDC 6400 computer system, and in September the conversion of all IBM 360 programs to this system was begun. It was expected that this conversion would be completed by January 1972. During the past year, the Datacentre processed approximately 80 requests for gravity and associated data from external agencies.

Studies involving use of the gravity-survey data have progressed favorably during the year. Progress has been made in studies of vertical movements of the earth's surface related to post-glacial rebound, the eustatic rise in sea level and the elastic deformation of the earth due to the melting of late-glacial ice sheets using simplified models of the earth. The movements of the ground are large and significant and required a re-evaluation of what is meant by eustatic sea-level change. It was concluded that there is no evidence of a substantial eustatic change in sea level in the last 6,000 years and that the information of past sea levels, when sufficiently widespread, can be an important tool for studying the deep mechanical structure of the earth.

Knowledge of rock-density variations is an important part of gravity interpretation. In the Western Canadian Basin of Alberta and Saskatchewan density (gamma-gamma) logs were collected from oil companies and used in a statistical study of sedimentary rock densities. The logs were subdivided into 34,000 intervals from a total footage of 814,000 feet. All data (density, lithology, formation tops and well details) were stored on four disk files. As a result of this study a new Bouguer-anomaly map reflecting anomalous mass distributions beneath the sedimentary fill has been produced, and a clearer understanding of variations in the density of the sediments themselves has been obtained.

Bouguer and isostatic anomalies for a section across the southern Canadian Cordillera extending from the Interior Plains to the Juan de Fuca Ridge off Vancouver Island have recently been interpreted in terms of geological and crustal structure. The Bouguer anomalies are related to near-surface density variations but are distorted by the effect of elevation. This effect was removed by computing isostatic anomalies for an Airy crust (thickness 30 km) with a density contrast of 0.4 g/cm^3. Regional changes in the amplitude of these anomalies were interpreted in terms of a number of crustal blocks of different thickness, and regional changes in the density of both crust and upper mantle. Changes in crustal thickness are supported by estimates from previous seismic experiments, and the significance of the derived models in terms of the plate-tectonic history of British Columbia has been examined.

Attempts have also been made to interpret the megastructure of the Canadian Shield in terms of plate tectonics. A hypothesis has been developed which suggests that the Superior and Churchill Provinces were once separated by seas but are now welded together along a geosuture which extends around the periphery of the Superior Province from Manitoba through Hudson Bay to the Labrador Trough.

The Division has recently commenced a new program of detailed gravity investigations in areas of known economic importance or potential. The first area studied was the Sudbury Basin. A rigorous study of old and new gravity data has resulted in a series of new gravity maps (Bouguer anomaly, first vertical derivative, second vertical derivative, etc.) and a new three-dimensional model of the Sudbury structure. In 1972, attention will be focussed on a section across the Labrador Trough which contains some of the best-preserved geosynclinal rocks in the Shield. Gravity is considered to be a potentially useful tool in elucidating crustal evolutionary processes in the Trough. Regional gravity measurements have already revealed a highly anomalous field related to the Trough and its margins.

A major program of earth-tide research was continued with emphasis on the problem of correcting for the attraction and loading effects of the ocean tide. This correction is necessary before the earth tide can be determined, and knowledge of the ocean-tide effect is itself useful because of its dependence on the mechanical structure of the crust and upper mantle. Methods for calculating the ocean-tide effect on inland earth-tide gravity and tilt measurements throughout the world have now been developed. The calculated results are consistent with North American and Western European observations but inconsistent with Eastern European and Asian observations. This result may indicate a systematic difference in the elastic parameters for Asia or an error in the assumed ocean-tide distribution.

A finite-element method for determining the Green's function of an earth with an arbitrary crust and upper mantle structure has been developed in co-operation with Dalhousie University. This method has been successfully applied at a coastal site on the Bay of Fundy where the crust appears to be 35 km thick and underlain by normal mantle differing from the Appalachian-type crustal structure under the Gulf of St. Lawrence.

Efforts in instrument research have been concentrated on developing an earth-tide-meter calibrator. A prototype has been developed in which a known sinusoidal vertical acceleration with a period of 100 seconds is applied. Calibration accuracy of between one and two per cent was achieved, and modifications now in progress are expected to improve the accuracy to 0.1 per cent at 1,000 seconds. Two North American gravimeters have been converted to recording earth-tide meters of the TRG-1 type.

A water-tube tiltmeter is also being tested. Resolution of 0.1 per cent tidal amplitude without apparent "stiction" or hysteresis effects has been demonstrated. This instrument should have wide application in the future.

Preparations have also been in progress during the year to develop equipment for systematic tilt measurements on the Arctic Ocean. This project is part of an international venture called Arctic Ice Dynamics Joint Experiment (AIDJEX) which will take place in 1974, although pilot studies began in 1969. Test measurements of ocean tilt have already been made in the Arctic Ocean and Gulf of St. Lawrence. The next test will be made in the Beaufort Sea in 1972.

In the field of physical geodesy, computations have been made of the deflection from gravity data at a few related astro-geodetic stations. Preliminary analysis has shown that for the required accuracy, additional gravity surveys around the computation point are required. These surveys are now in the planning stage. Methods are being developed for computation of the integral of Stoke's function over a block of given degree size, and the Division is studying its use in the computation of the standard error of geoidal height from a knowledge of the standard errors of the mean gravity values over individual blocks. A method is also being developed to compute fully normalized associated Legendre functions for use in spherical harmonic analysis of world-tide gravity data.

The Rock Physics Section continued its investigation of fossil meteorite craters and the related study of hypervelocity impacts. Unlike previous years, relatively little time has been spent on discovery, mapping, petrography and other descriptive aspects necessary to confirm the suspected impact origin of circular topographic features. The one notable exception is that Lake Wanapitei, at the northeastern end of the Sudbury Basin, has been definitely established as a meteorite crater. A circular negative Bouguer anomaly of 14 mgals in the lake, plus the discovery, in breccia boulders on the lakeshore, of the complete range of shock-deformation features typical of meteorite impact serves to confirm this origin. Coesite, a high-pressure silica polymorph occurring naturally only in meteorite craters, and possibly some meteorites, has been identified by X-ray in a largely glassy fragment of Lake Wanapitei breccia. Although coesite has been reported from a few other terrestrial craters, this is the first incontrovertible find in a Canadian crater. Skeleton Lake, Ontario, has been considered as a probable meteorite crater for a few years, and the existence of a circular-negative Bouguer anomaly in the lake has now been confirmed. Several other possible meteorite-crater sites have been noted and some have been rejected after a preliminary examination of appropriate maps and aerial photography, but most await further study. Eight samples suspected to be meteorites were submitted by both geologists and the public for identification. One of these was confirmed as a meteorite and added to the National Collection.

Recent petrographic studies have investigated the composition of impact melts and shock effect in potassium feldspars. In order to be able to equate natural shock-metamorphism features with conditions of formation, shock experiments were carried out on potash feldspars at the California Institute of Technology, where pressures up to 413 kb were attained.

In a continuing program in collaboration with the Geological Survey of Canada, lunar samples from Apollo 12 and 14 missions were investigated, with particular emphasis on shock effects in breccias and "fines." The Rock Physics Section was also called upon to provide scientific assistance during the geological training exercise for Apollo 16 astronauts held in the Sudbury Basin, Ontario.

SEISMOLOGY DIVISION

The standard network of seismic observatories equipped with short- and long-period seismographs continued operating as in the past, except that the Halifax station was reduced from a first-order to a second-order station with only one short-period vertical seismograph. In addition, to give better coverage of local events in eastern Canada, a second-order station similar to Halifax was installed at Fredericton, N. B.

An additional specialized narrow-band, high-gain, long- and short-period seismograph was installed at Suffield, Alberta, to supplement records from a similar seismograph operating at Alert, N.W.T. Similar but more sophisticated installations were planned for Penticton and Mould Bay later in 1971. Experiments on and modifications to these instruments are carried out in Ottawa before they are shipped to their ultimate destinations.

Improved use of available computer services resulted in a more rapid and complete check on the approximately 30,000 P phases reported annually by the network stations. This also permitted faster service to world data centres at Rockville, Maryland (NOA), and Edinburgh, Scotland (ISC).

Quality control and instrument calibration were maintained at all stations of the Canadian network by a schedule of routine field inspection trips by staff members.

Studies of Canadian seismicity continued. A project was undertaken jointly with Laval University to study the seismicity of the St. Lawrence Valley near Malbaie, Quebec, during the summer of 1970. The strong-motion seismic network deployed along the west coast of Canada obtained the first really significant strong-motion spectra from Canadian earthquakes. The results have been analysed and will be made available to the earthquake-engineering community.

A number of papers were published concerning primarily the core and inner-core structure of the earth. As a result of this work, travel times were calculated for previously unidentifiable seismic phases. Crustal-response functions for sources and station sites were determined theoretically, making possible the calculation of theoretical seismograms for nuclear explosions and teleseismic events. Surface waves, as recorded by the Canadian standard-station long-period network, were used to conduct a reconnaissance study of lithospheric thickness in Canada.

The results from a crustal-refraction survey in the Yellowknife region of the Northwest Territories were published. These show that the gross structure of the region is as simple as any yet discovered in Canada. One feature of interest is that the M discontinuity beneath the East Arm of Great Slave Lake, believed by geologists to be a major graben, is strongly depressed. Work continues on the massive suite of data recorded last year along a 100-km line near Yellowknife. Tentative results indicate the presence of a well-defined low-velocity channel in the upper crust.

The results from a crustal-refraction profile northwest of the Queen Elizabeth Islands out over the Arctic Ocean indicate that the crust is thinning from normal continental thickness at the coast to that of a normal oceanic crust under the Canadian Basin.

A major theoretical advance was achieved in the use of synthetic seismograms for the interpretation of crustal-refraction data obtained earlier in the province of Quebec. This demonstrates without doubt the existence of a low-velocity crustal layer along the Grenville Front. The layer provides an explanation for one of the largest gravity anomalies in eastern Canada.

During the year a synthesis of geophysical observations in the Canadian Cordillera was completed and sent to press. This work will provide guidance for geophysical activities in western Canada in the immediate future.

The geothermal group continued to make field measurements, mainly in the Shield, the Cordillera and the Arctic Islands. A gamma-ray spectrometer was put into operation, measuring the heat production of rock samples, in order to relate heat flow to heat production in the crust. Several papers have been published, including measurement and analysis of heat flow in the Kapuskasing area and estimates of the disturbance of heat flow due to climatic changes.

A great deal of effort has been diverted into permafrost studies. The techniques of measurement of temperature and thermal properties of rock that have been developed for heat flow work are of importance in permafrost research. Several dry oil-exploration wells in the Arctic have been preserved for accurate temperature surveying, and plans were made to make measurements of the thermal properties of frozen sediments in the Mackenzie Valley during the summer of 1971.

A tripartite long-period seismic array was commissioned in conjunction with the short-period Yellowknife Array at Yellowknife, N.W.T. Signals from the remote stations are transmitted to the base station by radio-telemetry links and, in the same way, all calibration and control functions are regulated from the base station. Planning was completed for changeover of the short-period array to two-way radio telemetry during 1970-71.

A detailed evaluation of present world-wide seismic capabilities entitled *Seismological Detection and Identification of Underground Nuclear Explosions,* was prepared for distribution by the Canadian Government at the 26th General Assembly of the United Nations.

An experimental study of laser-strain-gauge seismology was completed in the Ottawa seismic vaults. As a result, it was decided that mechanical rather than laser technology was more appropriate for this work. Instrumentation for a dual-band seismograph with optional recording was designed and built.

The geodynamics group continued to observe the earth's rotation and the motion of the pole with photographic zenith tubes (PZT) near Ottawa and Calgary. The latter instrument, since mid-1968, co-operates with the Royal Greenwich Observatory (Herstmonceux), on the same parallel, in a common program of observations to detect relative motions in longitude and latitude due to continental drift. Both instruments contribute with high weight to the international services monitoring rotation and polar motion (Bureau International de l'Heure, B.I.H., International Polar Motion Service, I.P.M.S.). Ottawa observations since 1956 have been reduced to a homogeneous basis and analysed for periodic and secular terms; an improved catalogue has been prepared. Detailed results of observations at the Ottawa and Calgary sites up to December 1970 are in press. Both are first-class instruments and are producing observations of polar motion to an accuracy which is unsurpassed in the world.

GEOMAGNETISM DIVISION

The information on the direction and intensity of the earth's magnetic field shown on the magnetic charts of Canada, aeronautical and marine navigation charts, and topographic maps comes from high-level airborne surveys carried out by the Division of Geomagnetism. The 1970 survey covered Canada's Arctic islands and about one-third of the Arctic Ocean—the part between the north geographic pole and the Canadian landmass, Greenland, and Spitzbergen. Magnetic measurements were recorded continuously along 22 parallel flight-lines spaced 40 miles apart, for a total of 50,000 miles of flying in a chartered DC-6B aircraft.

In addition to providing vital information for navigation on over-the-pole airline routes, the survey mapped the large-scale patterns of magnetic anomalies associated with ocean ridges. These anomalies trace the history of formation of the Arctic basin, and their study is expected to lead to a better understanding of the processes which have formed deposits of oil and gas in Canada's Arctic.

Magnetic charts must be revised every five years because the geomagnetic field is constantly changing. To bring up-to-date the data from earlier surveys, measurements are made on the ground every few years at each of 100 carefully marked repeat stations, uniformly distributed over the country. During 1970, 25 such stations were occupied, mainly in the western Arctic.

Charts at a scale of 1:10,000,000 were published showing the direction and rate of change of the magnetic field over Canada and the neighboring oceans as of 1970.

The natural variations of the geomagnetic field were recorded continuously at magnetic observatories in the following locations: Alert, Resolute, Baker Lake, and Mould Bay, all in the Northwest Territories; St. John's, Newfoundland; Poste de la Baleine, Quebec; Ottawa, Ontario; Churchill, Manitoba; Meanook, Alberta; and Victoria, British Columbia. In addition to the permanent observatories, unattended magnetic recording stations were operated in Manitoba at Lynn Lake, Thompson, The Pas, and Winnipeg, in a co-operative research project with the United States National Aeronautical and Space Administration involving the synchronous satellite ATS-5. Research included the study of several intense magnetic storms centred in the western Arctic and a detailed analysis of rapid variations (micropulsations) recorded simultaneously at four observatories covering a wide range of latitude.

Further field investigations in the Arctic islands revealed that the rocks of anomalously high electrical conductivity which underlie Prince Patrick and Melville Islands extend beneath Banks Island and the northern part of Victoria Island. A reasonable explanation of this remarkable feature remains to be found. Other field studies of deep crustal electrical conductivity were made in central British Columbia, Baffin Island, and southeastern Quebec.

The paleomagnetic group collected and studied the magnetization of rocks from the central Northwest Territories, and from Vancouver Island. Preliminary results indicate that 200 million years ago Vancouver Island was not part of the North American continent, but was thousands of miles away in the central Pacific.

Good progress was made in geomagnetic instrumentation. By the end of 1970, four of the ten magnetic observatories were equipped with instruments, developed in the Division's laboratories, which produce a record on digital magnetic tape, ready for the digital computer. This advance not only makes possible unmanned automatic observatories, but also makes practical sophisticated analyses by computer which were previously out of the question.

POLAR CONTINENTAL SHELF PROJECT

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Arctic coast of Canada, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Archipelago and the waters between them, and other areas that may be of special interest. The project serves in part to facilitate Arctic researches and surveys of other units of the Department of Energy, Mines and Resources; in part it carries out, with its own personnel, work that is unique within the Department; it also serves as the vehicle through which the investigations of other agencies are carried out in the Arctic Archipelago and the Arctic Ocean; and it provides facilities and support for approved university researches in the area.

The project's field survey will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean that are of interest to Canada and which can be reached with available logistics, and those parts of the archipelago and the mainland not studied by other agencies of the Department.

Field activities in 1971 were carried out from mid-February to early October. A small program of sea-ice investigations was undertaken in January, February and December. The main bases of operation were Tuktoyaktuk, Resolute Bay and Alert.

In addition to EMR, 42 other agencies were involved in or received assistance from the operations of the PCSP. Among them were 24 universities. Twenty agencies were associated with the Arctic Ice Dynamics Joint Experiment (AIDJEX) and the International Biological Project Tundra Ecosystem Study.

The 1971 program was, in the main, a continuation of that of 1970. The main emphasis was placed on the Beaufort Sea.

The following is a summary of the work done in 1971, by major scientific fields:

Climatology

Study was continued by a scientist from McGill University under contract to PCSP of the present behavior of a small high Arctic icecap—the Meighen Island icecap—and its influence on and reaction to the local climate. Emphasis was laid on the energy exchange between atmosphere and the earth's surface of known uniform physical properties.

Hydrography

A survey (ocean soundings) of the Beaufort Sea was made for charting at a scale of 1:500,000 by the PSCP Hydrographic Section with assistance from the Canadian Hydrographic Service (DOE). Soundings were also taken in Robeson Channel at a scale of 1:1,000,000, near Hans Island in Kennedy Channel at a scale of 1:1,000,000; and in the vicinity of Wrangel Bay at a scale of 1:10,000.

Sea-Ice Studies

For the tenth successive year, a systematic aerial survey was carried out of the distribution, nature and movement of sea ice in the main channels of the Arctic Archipelago.

Position Determination

Already existing control positions on the Greenland and Canadian coast were used in 1971 for a hydrographic survey of Robeson Channel. After an evaluation was made of the Omega navigation system and the Decca Lambda system, it was concluded that the Decca Lambda system was the most suitable navigational system in high latitudes.

Geology, Marine

Continuous seismic-reflection profiling and side-scan sonar work in the Mackenzie Bay area and Beaufort Sea area north of Tuktoyaktuk indicate a large ice-scour canyon, now almost completely filled up, to have existed in Mackenzie Bay. The existing Mackenzie canyon on the bathymetric charts is that part of the ice-scour canyon that has received the least amount of sediments since glacier retreat. These studies were undertaken by scientists of the Geological Survey of Canada, supported by the PCSP.

Geology, Terrestrial

The study of Cretaceous rocks in the Yukon coastal plain by the Geological Survey supported by PCSP was continued in order to outline the stratigraphic succession, lateral variations and the ancient environments of deposition to determine possible coal reserves and areas favorable for petroleum accumulation. An experimental study of

the use of "shallow seismic" techniques to investigate the occurrence, depth and thickness of permafrost in different local geological settings was begun. Preliminary maps of terrain and surficial deposits of the Coastal Plain, Alaskan boundary to Cape Bathurst, at a scale of 1:125,000 were completed and placed on open file (Geological Survey).

Investigations of Pleistocene stratigraphy by the Geological Survey throughout the length of the Eskimo Lakes were continued. Detailed mapping of Herschel Island was completed. Detailed mapping at a scale of 1:25,000 to locate sources of aggregate and delineate geologic problem areas in the vicinity of Tuktoyaktuk was begun. Studies on the occurrence of ground ice and permafrost thickness using resistivity and seismic methods continued. Investigations by the Geological Survey into the origin and growth of ground ice and temperatures in permafrost were also conducted in various areas of the Mackenzie Delta and Valley.

Geomagnetism

Studies of the anomaly in geomagnetic induction on Ellesmere Island by the Earth Physics Branch, supported by the PCSP were extended to the north, with four temporary stations on the ice of the Lincoln Sea northeast of Alert. Analysis of the data indicates that the principal features of the anomaly extend into the continental shelf.

Gravity

Regional mapping of gravity by scientists of the Earth Physics Branch, supported by the PCSP continued, approximately 1,600 gravity measurements being taken on the sea ice over the Beaufort Sea at a station interval of about four miles and approximately 900 measurements being taken over Banks Island at a station interval of about eight miles. A gravity map is being compiled for the Beaufort Sea and Banks Island at a scale of 1:1,000,000. An experimental study to investigate the use of gravity in locating and investigating the thickness of ground ice was conducted over Tuktoyaktuk Peninsula and Richards Island.

Geothermal Studies

Temperature measurements by the Earth Physics Branch have been made at yearly intervals in eleven deep boreholes to determine the thermal recovery from drilling and the equilibrium geothermal gradient. The equilibrium temperatures yield a permafrost thickness at the location. A program was begun to study the thermal regime of the subsurface and to measure the thermal parameters of the overburden material in permafrost terrains, first results being obtained in the vicinity of Fort Good Hope, N.W.T. These studies were supported by PCSP.

Glaciology

Studies of the mass balance and physical behavior of Arctic icecaps by PCSP glaciological section continue. Following studies of Meighen icecap, the crystallography and internal structure of the Devon Island icecap is being studied to determine its history and the climate of the region during the recent geological past. A core containing a complete sample of precipitation, particulate fallout and other impurities over the past 2,000 years has been obtained.

Frozen-Sea Research

The objective is to obtain a complete picture of seasonal variations in water structure associated with growth and decay of sea ice. It is hoped that precise measurement of salinity, temperature, currents and oceanographic conditions will lead to an explanation for vertical mixing associated with salt rejection by sea ice during growth. An under-ice traversing probe to record horizontal variations in temperature and salinity beneath growing sea ice is being developed. Work has begun on measuring the change of freezing point of sea water with pressure. Studies of runoff in Arctic regions have been completed as an aid to understanding seasonal changes in the surface waters. These studies are conducted by the Water Sector, Environment Canada, and extensively supported by PCSP.

AIDJEX

The Arctic Ice Dynamics Joint Experiment is a common purpose and a co-operative effort to understand quantitatively the interaction between the fields of motion of the atmosphere, the pack ice, and the liquid ocean. This understanding is basic to forecasting ice conditions and to assessing variations in surface/atmosphere circulation. Preparation for AIDJEX, whose main program is scheduled for 1973-74, are continuing, and a major pilot study was conducted in the Beaufort Sea in 1971. The purposes were to test instruments and techniques for measuring absolute and differential water-velocity profiles under freely drifting pack ice, determination of ice strain and deformation, observation and mapping of the undersurface of drifting ice, and determination of the differential translation of separated points on the drifting ice under

different wind conditions. As an associated part of this pilot experiment, methods were tested for determining the tilt of the ocean surface.

Other Activities

PCSP provided support for several other projects such as: a micrometeorological study of wind and temperature to establish air drag coefficients of the ice cover by Atlantic Oceanographic Laboratory; an investigation of beach characteristics in the Radstock Bay area by McMaster University; live capturing, tagging and branding of ringed seals by Fisheries Research Board; collection of about 700 species of insects to assist in the knowledge of distribution of insects in the north by Canada Dept. of Agriculture; population and movement of polar bears by Canadian Wildlife Service; chlorophyll and dissolved organic carbon content at the base of sea ice by the Dept. of Sea and Shore Fisheries, state of Maine, USA.

ATLANTIC GEOSCIENCE CENTRE

(During the period under review, i.e., April 1970-March 1971, the units now making up the Atlantic Geoscience Centre were part of the Water Sector. This Sector was later transferred to the Department of the Environment, with the exception of the above-noted units.)

HUDSON 70

Participation in the HUDSON 70 circumnavigation of the Americas, under way since November 1969, very much dominated the activities of both the Marine Geology and Geophysics Sections for this year. The HUDSON 70 cruise ended in October 1970, and with it the fieldwork and data acquisition of the program. Reduction and interpretation of results, however, will occupy both Sections for quite some time to come.

For the earth sciences the following activities and discoveries highlight the expedition:

(a) The completion of the longest gravity line along a meridian (150°W) from the Antarctic ice to the Alaskan shelf. This line will help provide a ground reference (accurate shape of the geoid) for U.S. satellite measurements of the height of the sea surface which are to begin in 1973.

(b) A geophysical survey off Canada's west coast provided information on the interaction and movement of large segments of the earth's crust and helped define the pattern of continental drift (sea-floor spreading). CSS *HUDSON* in combination with CNAV *ENDEAVOUR* carried out a seismic experiment which showed that the propagation of sound under the earth's crust varies directionally, contiguous with the direction of sea-floor spreading.

(c) An extensive bottom-sampling program established the sediment distribution in the Beaufort Sea. Also in the Beaufort Sea submarine ice-cored hills or pingoes and deep scours caused by movement of ground ice were discovered. Both features indicate potential hazards. The former, generated by the expansive force of freezing water originally locked in sandy aquifers, form shoals which may endanger navigation. Ice scouring could destroy man-made structures put down on the sea floor, such as pipe lines and well heads.

(d) Seismic refraction shooting established that Baffin Bay is underlain by oceanic crust, which provides an all-important clue to the unravelling of the geological history of Northeastern America and Greenland.

Sinking of ARROW

The grounding and sinking of the Liberian tanker *ARROW* in February 1970 released 2.5 million gallons of Bunker C oil, polluting Chedabucto Bay and its shore. This year has seen extensive research as a direct result of the *ARROW* disaster. Within the Geology Section the long-term observation on Crichton Island of natural cleaning processes is still going on. So far it has been established that some sandy portions of the seashore were cleaned in a matter of months. Conditions on bouldery and rocky shores, although greatly improved after a few months, apparently take some more time to permit erosion to remove the last stain.

General Research

Results of other research activities during this year may be summarized as follows:

Laboratory tests indicate that humic compounds associated with marine sediments exert a strong solubilizing

effect on trace metals. One gram of humic acid can liberate up to 0.7 gram of metal from insoluble salts.

Mercury in a river and estuary system is concentrated by suspended particles to levels 20 times that found in bottom sediments. In the case of the La Have estuary the metal may be exported to the ocean in quantities of one to two kilos.

The establishment of the pattern of sediment transport in the Bay of Fundy and Minas Basin was completed during this period, using a submersible for direct observations. These studies elucidate some of the problems related to the planning, construction and operation of a tidal power plant.

Seismic reflection studies suggest the presence of end-moraines parallel to the west coast of Newfoundland.

Compilation of geological and geophysical data obtained from the continental margin off Labrador and eastern Newfoundland is under way in order to establish the development of this margin.

The Regional Geology group has been compiling and analyzing geological and geophysical data that relate to various aspects of bedrock and surficial sediments underlying the Scotian Shelf and adjacent areas. The first of a number of 1:1,000,000 charts showing the distribution of unconsolidated sediments was published. Contour maps of the bedrock structures are in varying states of preparation.

Micropaleontologists monitored the environment by studying the seasonal variations and the geographical distribution of microorganisms (benthonic foraminifera) living near sewage and industrial outfalls.

With the scanning electron microscope, microstructures of foraminiferal tests were discovered that have not been reported before. These structures will assist in a better understanding of foraminiferal taxonomy and ecology and lead indirectly to a better foraminiferal biostratigraphy and paleoecology.

As special projects the construction of the new electric rock-coring drill deserves mentioning, since it makes possible the recovery of longer core samples of importance for petrological and textural analyses of bedrock, for the production of subsurface geology maps.

This year saw the completion of the analysis of the gravity data from the mid-Atlantic Ridge survey. This forms part of the continuing 45°N-to-46°N geotraverse project. Small-scale trends in structure, which had so far remained undetected, show up as a result of the trend analysis of gravity, magnetics and bathymetry.

Of prime importance for both the Geology and Geophysics Sections is the work that has been going on in the upgrading and improvement of the seismic-exploration techniques. This work is continuing and shows direct results by providing better seismic records in terms of penetration and resolution. The great improvement this year was the application of a slacking or yo-yo winch, enabling the hydrophone array to be stationary in the water while recording reflected signals. This operation immediately cut out an important part of the noise spectrum. Programs for data processing to further improve the signal/noise ratio (deverberation, stacking, cross correlation) are in advanced stages of preparation.

A new sonobuoy has been constructed, facilitating the shooting of complete crustal sections in the deep ocean. These crustal profiles are essential for the understanding of the deep processes that have shaped our earth and at the same time provide information for the correct interpretation of seismic reflection profiles. For work on the continental shelf where thick crust is encountered incorporation of recording systems in the buoys is being planned.

Work has started to improve the accessibility of geophysical data already collected by storing information in geographic order. This will allow a much more efficient usage of information, greatly improving its value. Plans are under way to improve the presentation of the data in a number of ways—numerical, profile, diagram, contoured chart, etc.—as required by the individual user.

Administration

The administrative units of the Department of Energy, Mines and Resources consist mainly of the executive offices of the Minister and senior officers and various supporting units serving the entire Department—Finance and Administration, Personnel and Organization, Public Relations and Information Services, Computer Science Centre.

During the year under review, an executive committee was formed at the highest level, with the task of co-ordinating departmental policy and planning, in the light of existing government policies and the activities of other federal departments. The committee consists of the deputy minister, who is chairman, the assistant deputy ministers, the senior advisers for finance and administration and personnel, and the director of the departmental planning branch.

A departmental management committee was also established, to deal with matters relating to overall departmental management and policies and to co-ordinate major projects. The committee is chaired by the deputy minister and consists of all members of the executive committee and senior departmental managers.

The Computer Science Centre, which serves the entire Department, was steadily increasing its computing capacity.

FINANCE AND ADMINISTRATION

The Finance and Administration Branch provides the Department with services in accounting, finance, program forecasts and estimates co-ordination, parliamentary matters, preparation and co-ordination of submissions to Treasury Board and the Governor in Council, co-ordination of memoranda to Cabinet, management of material, property planning and management, telecommunications, mail, central records, technical field support (material and equipment), and related areas. During the year, steps were taken to establish a departmental management-consulting service. This unit, when operative, will study management problems and assist in their solution throughout the department.

Planning was completed for the construction of additions to the laboratory wing and library of the Institute of Sedimentary and Petroleum Geology at Calgary. Plans were also furthered for the construction, by the Department of Public Works, of a high-rise general-purpose office building in EMR's complex on Booth Street in Ottawa.

Effective October 1, 1970, departmental purchasing was consolidated, with a small number of exceptions, in the Department of Supply and Services.

PERSONNEL AND ORGANIZATION

The Department, in its personnel administration, continued to deal with problems common to the whole Public Service—in fields such as job classification, staff relations and manpower appraisal and planning. In addition to these normal activities, because of a major interdepartmental reorganization, it planned and carried out, during the last quarter of 1970-71, the orderly transfer of the whole Water Sector and a part of the Department's administrative support personnel. This resulted in the transfer of 2,214 man-years' authority (Water Sector) and 81 headquarters administrative positions in support of this group.

At its peak employment date during the year, the Department had 6,200 employees on strength, with the technical,

scientific and professional categories accounting for approximately 60 per cent. This number included over 1,200 post-secondary school students who were employed on field surveys and in laboratories and offices during the summer. During the latter half of the year, planning was carried out for an exceptional student employment effort for the summer of 1971. These proposals, which were eventually approved by the government, resulted in the employment of some 1,650 more students in the summer of 1971 than were provided for in the original budget.

A total of 1,690 continuing appointments were made during the year, including new appointments, promotions and reclassifications. During probation, 25 employees were rejected and released.

The new departmental safety and accident prevention program was established and put into effect during the year. Despite the fact that the maximum departmental population reached its highest point, the trend towards a progressive increase in the number of accidents was reversed.

In aid of effective manpower planning, appraisal systems were designed and developed for occupational groups in the Scientific and Professional, Administrative and Foreign Service and Technical categories. A number of analytical studies concerning manpower forecasting and utilization were carried out. And a manpower planning process, for general application throughout the Department, was developed.

In training and development, some 537 employees participated in 28 in-house courses—mainly in management-improvement techniques and supervision. Language training, mainly French, was given to 326 employees. A total of 64 employees were assisted to varying degrees in furthering their formal education at universities and institutes.

An organizational study of the Water Sector, aimed at enabling it to assume its assigned role in the implementation of the Canada Water Act, was undertaken. Organization studies and reviews were also carried out in the Mineral Resources Branch and in connection with the proposed Remote Sensing Centre. A study of the senior structure of the Department was also commenced following the decision to transfer the Water Sector to the Department of the Environment.

The Department's Incentive Award Program continued to be a vigorous one. The 1970 Outstanding Achievement Award of the Public Service was presented to an officer of Energy, Mines and Resources—Dr. J.M. Harrison, Assistant Deputy Minister, Mines and Geosciences. The Department recommended six officers for Merit Awards during the year and continued to be one of the leaders within the Public Service in the use of this management tool. In the Suggestion Award Program, too, an upward trend continued in savings resulting from suggestions implemented.

The Department's health program, especially in the areas of addiction and mental illness, continued to be effective. During the year, several other departments sought advice and guidance on the implementation of similar programs.

The conversion of positions to the new classification system was largely completed and the backlog of classification grievances was overcome. Classification actions continued high, however—2,755 jobs were reviewed during the year. Training in job-description writing and classification was provided to line management by means of seminars and workshops.

The administration of 35 collective agreements was an important aspect of personnel management during the year's operations. Management was not, for the most part, familiar with a collective bargaining regime, and a considerable amount of time and effort was devoted to development of guidelines and advice to and training of managers. Departmental officers effectively participated, on behalf of Treasury Board, in bargaining activities in respect of eight different occupational groups.

The effects of collective agreements on field survey operations required special study, adaptation and negotiation to obviate difficulties caused by the variegated make-up of parties.

PUBLIC RELATIONS AND INFORMATION SERVICES

The Public Relations and Information Services Branch informs the public of the work done by the various units of the Department and the reasons for departmental policies.

HUDSON 70 was the Department's scientific highlight of the year as the Canadian Scientific Ship *HUDSON* carried out her 11-month 41,000-mile oceanographic expedition around South and North America. Ministerial news conferences were held in Valparaiso, Chile, in April; in Vancouver in June before the ship proceeded to the Arctic to carry out an extensive program of work in the Beaufort

Sea, returning to Halifax through the Northwest Passage, and at Halifax in October at the end of the expedition. Throughout the expedition, news coverage was excellent. HUDSON 70 medals commemorating the epic voyage were given out to all who participated in its planning and execution as well as to the Governor General, members of the Senate and House of Commons and newsmen who travelled to Chile.

Over 800,000 copies of the pamphlet, *Water Pollution and You,* were requested and distributed to students and teachers of high schools and colleges. A series of four water pamphlets was produced in response to requests for information on water pollution and water management.

News conferences were arranged in connection with amendments to the Canada Water Act, the Qu'appelle River Basin Agreement, the Saint John River Basin Agreement, the opening of the Research and Development Building of the Canada Centre for Inland Waters, the signing ceremony for the financing of the Hydro Quebec Research Institute, and Canadian Government approval of applications for the export of natural gas from Canada.

Information arrangements were made for the Canadian Conference on Coal at Vancouver, the Eastern Offshore Symposium in Ottawa, and the Conference on Achieving Environmental Awareness of the Canadian Commission for UNESCO in Hamilton.

The Department sponsored two classroom filmstrips, *Aluminum* and *Iron and Steel* in English and French. Twelve one-minute TV newsclips on water pollution and water management, geophysics, geology and mapping were produced in both languages and distributed and used nationally.

Two films were completed in co-operation with other government departments: a short film on the voyage into the Arctic of the *MANHATTAN* and a half-hour documentary of the *ARROW* oil spill on the east coast. The film *Every Square Inch* and an internal training film on hydrographic surveying were produced.

During the year, the Public Relations and Information Branch handled some 23,000 pieces of mail, including requests for publications and enquiries of a general nature.

The Publishing Division maintained a heavy schedule that included the issue of five oversize books as well as the normal quota of publications of a scientific or technical nature originating from all branches. In addition, the Division undertook to continue editorial responsibility for a number of publications of the former Policy and Planning Branch, now with the Department of the Environment.

A much higher proportion of contemporary design in covers and layout was evident during the year, and a new design concept was proposed for the Geological Survey of Canada series.

The French Publishing Section was designated as a Francophone unit.

The Director of PRIS was seconded to Treasury Board for a six-month period to direct the preparation of a Career Development Manpower Plan for the Information Service Officers of the federal government. Four Information Service Officers served on three of the project's six study teams.

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

annual report 1971-72

Hon. Donald S. Macdonald, Minister

Department of ENERGY, MINES AND RESOURCES Annual Report 1971-72

Hon. Donald S. Macdonald, Minister

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Artist's drawing of new EMR tower building, Booth St.

Introduction

The Department of Energy, Mines and Resources is the federal government's principal agency for the discovery and assessment of Canada's potential in a broad range of non-renewable resources—fuels, metals, industrial minerals; for the dissemination of many types of scientific and technical information; and for the analysis of economic and industrial trends in the fields of energy and mineral resources, and for policy development in those fields.

Nowhere was this responsibility better illustrated than in the stepped-up activities of EMR's energy staff, the team responsible for collecting and interpreting the relevant data that serve as a basis for governmental policy. The growing tempo of offshore exploration on Canada's continental shelves, especially on the east coast, also required constant supervision on the part of the department. The resurgence of coal use and coal exports, the ever-changing situation of nuclear power, and the ecological and social considerations attending the construction of thermal and hydroelectric power plants are placing heavy burdens on the analytical and decision-making components of the department.

Equally weighty are the developments that demand attention and decision in other mineral-resource fields. Canada has always been a large exporter of raw mineral materials. It is held to be economically and politically desirable for a nation to process its own raw materials at home; but apart from the stern realities of differential wage and price structures in the world's industrial nations, further processing may also be opposed by ecological considerations: metal smelters and refineries often release noxious gases and liquids into the air and the waters. This is only one example of the type of social and economic dilemmas with which EMR mineral experts must come to grips.

Greater social and economic awareness is also evident in the work of such essentially scientific agencies as the Geological Survey of Canada. The much-debated development proposals for the Mackenzie Valley have prompted an intense effort aimed at understanding the peculiar terrain of that area, and its potential reaction to the various stresses that advancing civilization may place on it. But in the highly populated and industrialized southern parts of Canada, too, geological research has moved into the compilation and analysis of terrain data that will provide a better basis for urban and industrial planning.

Mining and metallurgical research in EMR laboratories has for many years contributed to the technological advancement of Canadian industry and has helped many a company to make use of low-grade or hard-to-process minerals and ores. Such research and development may be particularly important in those regions that lag in economic and industrial development.

Now a significant proportion of this research capability is directed toward ways and means of reducing air and water pollution from mining and metallurgical operations. One of the most common noxious gases released into the atmosphere by smelters is sulphur dioxide. Mines Branch investigators have developed a number of modifications to existing processes that allow this gas to be turned into solid sulphur compounds, whose removal is easily accomplished. Similar aims are being pursued in improving the combustion of fossil fuels so as to reduce the emission of polluting fumes into the air.

The safety and well-being of Canadians is also an important research goal of EMR's seismologists, who record earth tremors throughout Canada and compile maps that show the probability of earthquakes in the various regions and assist builders in planning earthquake-resistant structures, as required. In an interna-

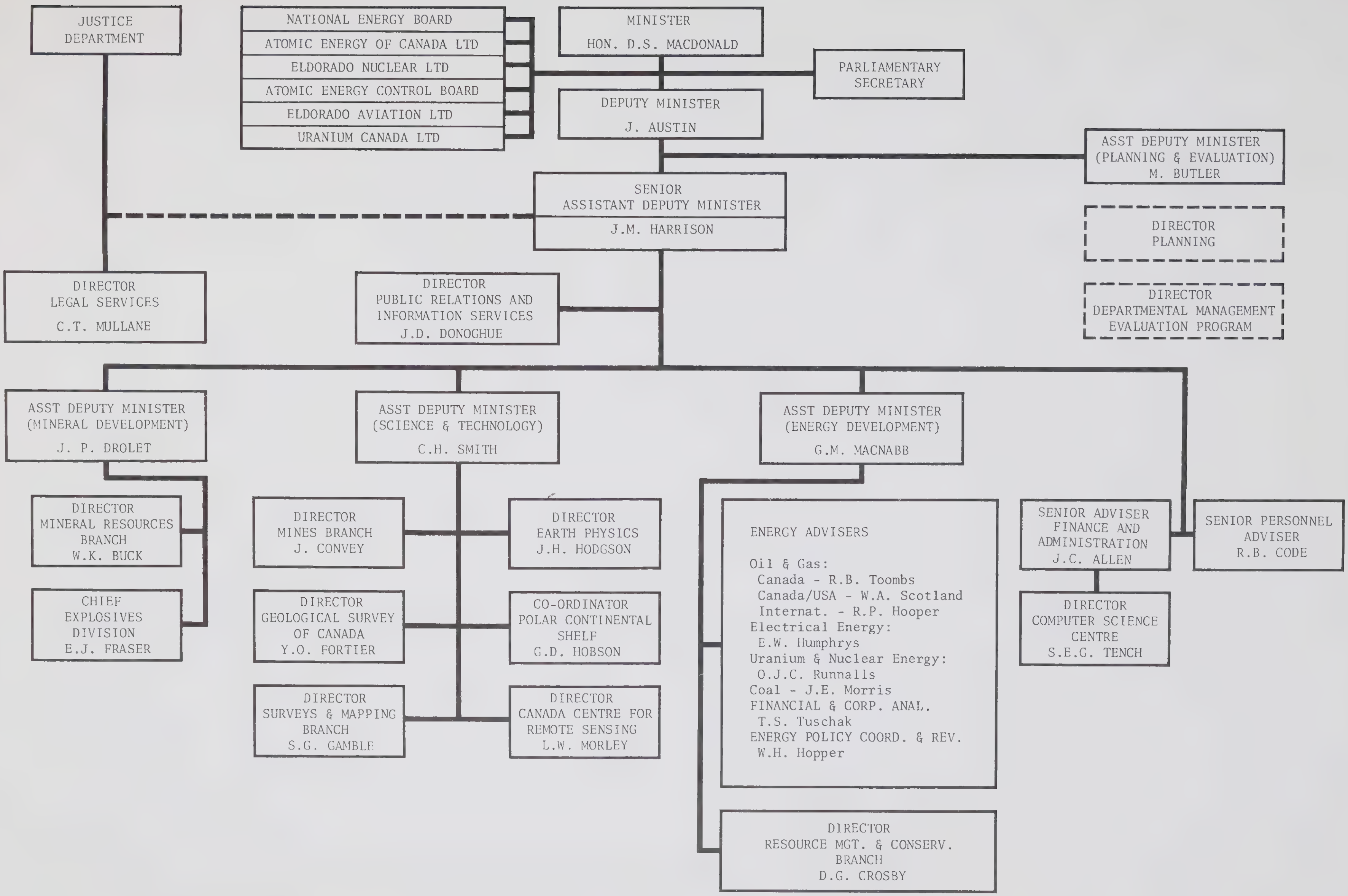
tional setting, the sensitive seismographs in the analytical methods developed by EMR's seismologists have enabled them to detect atomic explosions around the world.

A country as large and as thinly populated as Canada is particularly dependent for communications and development on the ready availability of accurate medium-scale maps of many types. These constitute one of the main products of EMR's surveying and mapping units. Over four million maps and air charts were distributed to civilian and military customers during 1971–72, evidence of increasing interest in summer homes and land investment, vacation travel, resource development, and the use of maps in education.

A new field of research closely allied to mapping is remote sensing. This activity is carried out with various types of sensors—chiefly photographic cameras and television-type scanners—that are mounted in specially equipped aircraft and in satellites. The year in review saw the establishment of the Canada Centre for Remote Sensing, which was to co-ordinate the use of airborne sensing throughout Canada and was also preparing for the reception and processing of imagery from the first Earth Resources Technology Satellite (ERTS-A) that was subsequently placed into orbit around the earth by the U.S. National Aeronautics and Space Administration. The knowledge of Canada's land and water environment that will be gained through remote sensing will be of great value to planners in the fields of agriculture, forestry, water management, transportation routes, etc.

Research planning and policy formulation in EMR benefited considerably from the deliberations of a number of advisory committees whose members are drawn from the federal and provincial governments, educational institutions, and private industry. They are the National Advisory Committees on Research in the Geological Sciences, on Control Surveys and Mapping, on Mining and Metallurgical Research, on the Mining Industry, and on Petroleum. The first three committees are concerned mainly with the exchange of information and the encouragement of scientific research in their respective fields; the last two are concerned mainly with economic trends and policies in the mining and petroleum industries.

These are only a few indications of the various types of research and analysis carried on by the Department of Energy, Mines and Resources. Greater detail will be found in the body of the report itself. Those readers who have professional interests in the various aspects of EMR activities will find them in the large variety of scientific and technical publications produced by the operating branches.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NATIONAL ENERGY BOARD
ATOMIC ENERGY OF CANADA LTD
ELDORADO NUCLEAR LTD
ATOMIC ENERGY CONTROL BOARD
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March 1972

Resource Inventory and Potential

MAPPING

Topographic Mapping

The Department of Energy, Mines and Resources, which is Canada's principal mapping agency, produces a great variety of maps and charts for many different purposes. Topographic maps are based on geodetic and topographic surveys, supported by air photography. Other maps feature Canada's geology, geophysical characteristics, land use, etc., and serve technological and scientific purposes.

Topographic coverage of Canada was increased considerably during 1971–72. Of the 418 National Topographic Series maps forwarded for reproduction, 136 were new and 282 were revisions.

The demand for photomaps continues to increase. A substantial contract was awarded for the production of 43 contoured photomaps of the Mackenzie River area at the scale of 1:50,000, together with a negative for the production of line maps.

The cartographic-services staff of the department compiled and/or drafted 553 maps. This included the drafting of 348 new and revised manuscripts for the National Topographic Series; cartographic services were also provided to other agencies and resulted in the production of 157 maps.

In the International Map of the World Series, 24 maps have been published and a further seven were in production. Work continued on the 1:125,000 scale map series, on the first-edition map of North America at 1:10,000,000, on various special-purpose maps, such as those showing Canada Manpower Centres and census areas, and on maps for the Representation Commissioner.

The Surveys and Mapping Branch made progress in automating its map compilation by acquiring new equipment and by improving its use and mastery of existing equipment.

By the end of the fiscal year, fifty per cent of the *National Atlas of Canada* had been printed in both English and French; completion is scheduled for 1973.

Topographical mapping was complemented by geodetic surveys. During the field year, 25 geodetic parties established vertical and horizontal control throughout Canada. First-order levelling was carried out in five provinces. High-precision levelling along the north shore of Lake Erie, which was done in the metric system, was a continuation of the International Great Lakes Datum re-evaluation.

Horizontal geodetic control was carried out by a number of field parties. Of note was the Aerodist network in northern Manitoba, northern Saskatchewan and the Northwest Territories, covering 91,000 square miles and adding 38 new control points to the system. (The Aerodist technique combines the use of electronic distance-measurement and aircraft.) In several areas horizontal control was done co-operatively with provincial agencies. The Geodetic Survey also made the first attempt to extend a first-order horizontal

control (high-precision control) by trilateration, i.e., the measuring of the sides of triangles rather than of the angles. The method proved highly satisfactory. Two helicopter-supported parties established control for 1:50,000 mapping: one covered 59,000 square miles in the District of Mackenzie north of Yellowknife, and the other provided vertical control over 127,000 square miles in northern Quebec and Labrador. Progress was made in automation and training, in the review of existing geodetic networks and in the improvement of survey technology.

Map distribution by the Surveys and Mapping Branch continued to increase at an average rate of five per cent, and over four million maps and air charts were distributed to civilian and military customers in 1971–72. Revenue from sales increased by $36,000, to a total of $577,572.

The increasing demand for maps is attributed to increasing interest in summer homes and land investment, vacation travel, resource development, and the use of maps in education.

Air Photography

Plans were completed during the fiscal year to move the reproduction centre of the National Air Photo Library into a new building scheduled to house also the Canada Centre for Remote Sensing. This would provide the reproduction centre with better accommodation, and would also ensure a rapid and effective flow of satellite data from the Canada Centre for Remote Sensing to the photo facilities once the Earth Resources Technology Satellite began its operations.

During the year the reproduction centre of the National Air Photo Library filled 11,238 customer orders for survey photography and remote-sensing imagery. This necessitated the production of more than one million photographic items, and represented an increase in customer requests of 36 per cent over the preceding year. Enlarged premises at the Ottawa headquarters of the library and new stereoscopic viewers and light tables will make it easier for customers to study items from the 3,660,000 air photos listed in the library catalogue.

For reasons of economy and efficiency the department completed plans for combining the Calgary branch of the National Air Photo Library with the publications unit of the Institute of Sedimentary and Petroleum Geology in that city.

The Interdepartmental Committee on Aerial Surveys, whose executive is housed in the department, coordinates the air-photo requirements of federal government departments. Private survey companies under government contract flew 61,951 line miles of photo coverage during the past year.

Geographical Names

The standardization of geographical names throughout the country is a prerequisite for reliable maps as well as for numerous other activities. During the fiscal year 1971–72 the secretariat of the Canadian Permanent Committee on Geographical Names investigated 16,339 names; of these 7,914 were new decisions. The secretariat also compiled or revised a number of territorial and provincial gazetteers, and carried out research on place names.

Geological and Geophysical Mapping

Although the layman, when confronted with the word "map," is most likely to think of topographic or road maps, the field is much broader and embraces the display of a wide range of scientific findings about the earth's crust in a map setting. This includes geological, geomagnetic, gravity, seismologic and other maps.

A systematic geological framework, developed to consistent standards, is the basis for estimating the potential for mineral and fuel resources in Canada. This framework is identified by the national bedrock reconnaissance. Mapping has been carried out by the Geological Survey since its inception in 1842, and reconnaissance maps at a minimum scale of one inch to eight miles are expected to be available for all of Canada by 1976.

Such mapping, in the field season of 1971, included Operation Torngat in Labrador–Quebec, which during the past three years has covered 65,000 square miles, and the near-completion of mapping of 15,000 square miles in the Yukon Territory. Reconnaissance mapping of the surficial deposits of Melville Island in the Arctic was started. This is the last major arctic island for which such information is not available, and the study is being undertaken as a basis for the territorial land-use regulations and petroleum exploration. More detailed reconnaissance mapping was done on the Canadian Shield, and along the British Columbia coast where the rock units are similar to those elsewhere

in the province that contain deposits of molybdenum and copper.

Other reconnaissance mapping was done in northern and central British Columbia, Ellesmere Island, Devon Island, Melville Peninsula, the Daly Bay area of the District of Keewatin, the Snow Lake area of Manitoba, and Harp Lake in the eastern Canadian Shield.

The greatly increased interest in the resource potential of Canada's extensive continental shelves—submarine extensions of the continent that vary from a few miles to hundreds of miles—has resulted in more extensive geological studies. The Geological Survey has offices in Vancouver, B.C., and Dartmouth, N.S. (Atlantic Geoscience Centre); both were engaged in marine geology during the year. On the west coast, offshore geological and geophysical surveys were made along traverses at right angles to the coast line for basin analysis, determination of fuel and mineral potential, delineation of the continental margin, and engineering and environmental considerations for seabed development on the shelf and slope. The staff at Dartmouth analyzed subsurface data from petroleum basins in eastern Canada and from the Atlantic continental shelf; they also carried out a geological survey of Hudson Bay with the aid of the submersible *Pisces III*.

Many geological mapping activities depend on information supplied by specialists in the various disciplines that are associated with geology. Paleontological research into the remains of ancient sea- and land-dwelling plants and animals is one of these. During the report period field studies were carried out in the arctic islands, Mackenzie Mountains, Mackenzie Delta, northern Yukon, northern Manitoba, southwestern Alberta, eastern British Columbia and Newfoundland. In addition, 190 reports were prepared on more than 2,400 collections of fossils; fossil spores and mosses were studied, and microfossils from well cuttings and surface outcrops were examined.

Laboratory specialists carried out 178 potassium-argon age determinations of rocks. The officer in charge of the geochronology laboratory spent the first half of the year assisting in the establishment of a similar laboratory at Laval University, Quebec.

Radiocarbon dating is used on material less than 30,000 years old. During the report period, 175 such determinations were made, mostly on geological material, but eleven determinations were made on archeological material submitted by the National Museum of Man.

The Geological Survey maintains at its Institute of Sedimentary and Petroleum Geology, Calgary, a repository of drill cores and samples from wells drilled in areas under federal jurisdiction, mainly the Northwest Territories, the Yukon Territory and the continental shelves. The repository is used by scientists and exploration geologists.

Geomagnetic charts are an important aid in understanding the structure of the earth's crust—the repository of all mineral resources accessible to man. They are also an essential aid in navigation. During the year the department published four magnetic charts of Canada at a scale of 1:10,000,000. A special magnetic chart of the Canadian Arctic was produced at the request of the Canadian Hydrographic Service. A complete set of magnetic charts of British Columbia at a scale of 1:2,000,000 has been compiled and was scheduled for publication in 1972. In addition, 329 aeromagnetic maps were issued by the Geological Survey as part of the federal-provincial aeromagnetic program.

Considerable field work on geomagnetism was done in various parts of Canada, particularly in the Canadian Shield. Study of paleomagnetism in rock may reveal the direction in which these rocks were oriented millions of years ago. This, in turn, may lead to theories on the widening of oceans and continental drift.

Staff of the Geomagnetism Division carried out various studies on geomagnetism and its relation to electrical currents flowing in the earth and the sea.

Like geomagnetism, gravity variations in the earth's crust help in the search for resources. Field surveys to extend national gravity mapping were continued in the Arctic, in British Columbia and in the eastern offshore region. In British Columbia, a detailed gravity survey of the Guichon batholith (a rock mass formed at considerable depth) done in co-operation with the British Columbia Department of Mines and the University of British Columbia suggests a relationship between minimum gravity values and porphyry-copper deposits.

An important aid in understanding the long-term behavior of the earth's crust and in mineral exploration is investigation into the variations of gravity. For example, gravity measurements make it possible to trace vertical movements in the earth's crust resulting from the melting of the vast ice masses that covered much of the northern hemisphere during the latest ice age. Facilities have been built up during the last few years for predic-

ting the loading effects of the ocean tide, which in turn helps in investigating coastal structure and regional variations in gravity data. Dalhousie University and the University of New Brunswick are co-operating in this program.

A gravimeter was recently operated on the ice of the Beaufort Sea to determine the feasibility of measuring the deep-ocean tide by this method.

Among other gravity studies, data on the density of sedimentary rocks were collected from oil companies operating in Alberta and Saskatchewan, to gain a better understanding of variations in the density of the sedimentary strata in the Prairies; gravity anomalies in the southern Canadian Cordillera were interpreted in terms of geological and crustal structure; the structural history of the Canadian Shield was studied; a series of new gravity maps was issued for the Sudbury area, which has a known economic potential; fossil meteorite craters were investigated; lunar rock samples made available by the United States were studied jointly by the Geological Survey of Canada and U.S. scientists.

The various gravity surveys have been tied into the Primary Gravity Network of Canada, which in turn is tied to the International Gravity Standardization Network 1971 (IGSN 1971).

The storage and retrieval of gravity data were recently revised and converted to the department's new computer. Requests from exploration companies for all forms of gravity data continued to increase during 1971.

The Seismology Division of the department completed a reconnaissance of lithospheric thickness in Canada with the use of surface waves, and an experiment designed to study the tectonic fabric and development of the Rocky Mountains with digital-recording long-period seismographs. Instrument assembly and design for this experiment went parallel with the development of essential new techniques for processing and analyzing data.

Other seismological studies concerned the structure of the crust and upper mantle, and one interesting series of papers produced a revised model of the physical make-up of the earth's core.

Mapping for resource and scientific purposes in the arctic islands has benefited greatly from the logistic and other support provided for many years by the department's Polar Continental Shelf Project group. The field surveys carried on or aided by this group began with an emphasis on the Queen Elizabeth Islands, but they will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean that are of interest to Canada and which can be reached with available logistics, and those parts of the arctic islands and the mainland not studied by other branches of the department.

An interesting study under this head was a continuous bottom profiling in Mackenzie Bay and Beaufort Sea with seismic reflection and sidescan sonar, which indicates that a large ice-scour canyon, now almost completely filled in, once existed in Mackenzie Bay; the canyon shown on current bathymetric (deep-sea) hydrographic charts is what remains since the retreat of the last glacier. Gravity mapping was also carried out in the Beaufort Sea.

SEARCH FOR AND EVALUATION OF RESOURCES

Search for Resources

Many of the detailed studies by the Geological Survey of Canada contribute to the search for non-renewable mineral resources. Indeed, of the 99 parties that were in the field in 1971, some 20 were working toward this end; of course, many of the office and laboratory studies included in the 490 scientific projects worked on during the year served this purpose.

The geological staff intensified its analysis of northern and arctic petroleum basins. Because arctic Canada may well become one of the major oil regions of the world, and because this region is entirely under the jurisdiction of the federal government, the data needed as a base for policy decisions are most logically obtained by federal departments. The government is faced with the responsibility of both encouraging and controlling the surge of activity. Regulations must be based on a detailed knowledge of the sedimentary column. As the principal geological agency of the federal government, the responsibility for providing the required data falls on the Geological Survey.

After some years of being the Cinderella of the energy minerals, coal has again become an eagerly sought mineral. During the report period, samples were obtained by geologists from active mines and exploratory openings in the upper Elk River and Crowsnest areas

of southeastern British Columbia and the Sukunka River area in British Columbia as well as from the Blairmore, Mountain Park and Smoky River areas of Alberta. These samples will provide material for studies of coal quality and petrographic composition. Other samples were collected for research on ancient spores and pollen.

The Canadian Shield has proved to be a vast storehouse of mineral wealth in its southern, better-known reaches, and it is logical to assume that it should be equally rich in the north. Geologists have started an in-depth study of a 40,000-square-mile area north of Yellowknife where the gold mines will soon be exhausted. Part of this study consists of re-mapping, but a principal aspect is a geochemical survey of lake sediments and lake waters. A trial run done in 1971, fully justified the full-scale geochemcial survey planned for the season of 1972.

In order to test the applicability of geochemical techniques to permafrost terrain, detailed mapping was carried out in the nickel-rich Cape Smith–Wakeham Bay belt of northern Quebec and around a lead-zinc deposit on Little Cornwallis Island. It appears that trace elements are sufficiently dispersed throughout the sampled materials to make geochemical exploration feasible at a detailed and at a regional scale. Geochemistry is a relatively inexpensive exploration tool, and, even if not invariably reliable, it probably will have widespread use in assessing the mineral potential of our northern areas.

During the period covered by this report, funds available through the federal government's Special Employment Plan made possible a major project designed to evaluate further the mineral potential of northwestern Quebec and northeastern Ontario, an area where gold mining, long the economic mainstay, is in decline. Sampling of lake bottoms and surficial materials was carried out, and the results have been compiled in the form of maps for each of the 50 Quebec and Ontario townships involved.

Other field projects aimed at the discovery of mineral resources were: a study to relate dispersion patterns of loose surface materials to their source in the bedrock; a regional geochemical census of plutonic (formed at great depth) rocks in the eastern Yukon to aid exploration for metal ores; a project to aid the search for mercury, a possible "pathfinder" element in base-metals exploration; a stratigraphic, sedimentological and paleontological study in the north-central District of Mackenzie to aid in prospecting, especially for copper; a stratigraphic and metallogenetic study in the southern District of Keewatin outlining the potential for several types of ores.

One section of the Geological Survey collects and synthesizes information on the mineral resources of Canada in order to outline regions and geological environments likely to contain mineral deposits. During the past year, the staff of this section carried out studies on nickel, copper, zinc, silver and tin. As a result, several new criteria were developed for identifying areas with a potential for these metals. One interesting conclusion is that, contrary to commonly held theories, metamorphism is not necessarily detrimental to ore potential and may actually improve it. As large parts of the Canadian Shield have undergone high grade metamorphism, this conclusion could be of considerable importance.

Field work on mineral potential was also carried out in the central mineral belt of Newfoundland.

Evaluation of Fuels and Other Resources

The search for and discovery of mineral resources must be complemented by far-ranging analytical studies of their use and marketing, both in Canada and abroad. Such studies are essential for the formulation of fiscal and other government policies aimed at keeping Canada competitive in international markets while safeguarding the nation's resource potential.

Until the late 1960's almost all exploration for oil and gas was concentrated in the Prairies and the western Foothills. Now there is considerable interest in what may be described as Canada's frontier regions: the area north of 60 degrees latitude, including the arctic islands, and the continental shelf areas along with Hudson Bay. There is also increasing interest in the potential of the Athabasca oil sands in northern Alberta and other areas containing heavy oils. The oil-sands area, which may contain as much as 600 billion barrels of oil, is one of the richest fuel sources in the world. However, the oil is extremely difficult to extract, and this makes its economic situation uncertain.

World demand for oil will probably more than double in the next 15 years, which will put great pressure on all available resources and increase Canada's export opportunities, especially to the United States.

Whether such opportunities should be grasped is a matter of continuing debate. EMR is conducting an appraisal of Canada's oil and gas resources that will increase in accuracy as more geological and exploration data flow in.

Coal, which was not much in demand in recent years, has experienced a remarkable comeback, due to large measure to the growing needs of the metallurgical industry, especially that of Japan, and to fuel power stations at home. It has also become apparent that the world's supply of oil and gas will not be able to meet demand in the long term, and as the prices of these fuels rise prudent planning suggests greater use of our abundant coal reserves for steam raising in thermal power plants.

Throughout the 1960's, Canada's annual coal production was about 11 million tons. By 1971 it had risen to 19.4 million tons, and continuing growth in production can be expected, to an estimated 40 million tons per year in the late 70's and 60 million tons in the early 80's. Exports, mainly to Japan, have also risen, from 1¼ million tons in the 1960's to 7.7 million tons in 1971.

The department together with western provincial authorities has undertaken a comprehensive inventory of Canada's coal resources. A preliminary geological study related to this inventory has indicated that coal reserves in western Canada amount to about 118 billion tons, a tremendous reserve. However, these reserves are physical deposits which may not be economical with today's technology.

During the 1950's demand for uranium increased rapidly, mainly because of the manufacture of nuclear weapons in the United States and Britain. Once these demands ceased, Canadian uranium mines began to experience great marketing difficulties, and it was then that the federal government stepped in with its stockpiling program. These measures were designed not only to avoid serious social problems in the mining towns but also to meet the predicted demands for uranium in the future, particular to fuel nuclear reactors. This demand is now increasing at a rate of nearly 30 per cent annually.

About 75 per cent of Canada's electrical energy is derived from hydraulic resources. Although this proportion will decrease, new hydroelectric power plants will remain an important element for at least two decades, especially in such provinces as Newfoundland and Labrador, Quebec, Manitoba and British Columbia.

Future estimates of undeveloped hydroelectric resources will have to take better account of the economic realities of bringing them to production stage by the construction of power plants, dams, transmission lines, etc., as compared with the cost of building and operating plants fired by fossil or uranium fuels. Without such comparisons any estimates of hydroelectric capacity would be meaningless. Concern for the environment must be added to the economic restrictions. The department is making plans for an inventory of hydroelectric resources that will be comparable to the inventory of fuel resources and provide a better basis for economic and policy options.

Through its Resource Management and Conservation Branch, the department gains additional information on the oil and gas potential of the continental shelf off the east and west coasts of Canada and in Hudson Bay and Hudson Strait. Such information assists the department in regulating offshore exploration, which is now at a high peak, and it also contributes to the national inventory of Canada's oil and gas potential.

The department's Mineral Resources Branch collects and analyzes economic information on all of Canada's non-renewable resources, thus providing the federal government with a basis for policies governing taxation, aid to regional mineral development, import duties on foreign mineral commodities, negotiations with foreign governments on the flow of mineral commodities in world markets, and social effects of mineral development.

In recent years, much of the growth in Canadian mineral production has resulted from foreign demand, particularly from the United States and Japan. Is Canada's resource base sufficient to maintain its share of foreign markets and to supply the market at home? This is the question that motivates much of the economic and technical studies carried out in the department. One such study concerned the possible extension of the railway network of British Columbia toward the Yukon, taking account of the mineral and forestry potential along several proposed routes, and the development that might be stimulated. Another study, carried out in co-operation with the Manitoba Department of Mines, Resources and Environmental Management, produced an estimate of the undiscovered mineral resources of the Canadian Shield in Manitoba.

Still other such studies concerned the base-metal potential of the Timmins-Val d'Or "gold belt," the oil-and-gas potential of the Yukon and the arctic islands, and the abundance of major metals in Canada and their distribution.

The Mineral Resources Branch maintains an inventory of 14,000 Canadian mineral occurrences, giving the location, geology, history of ownership, development and other data. The inventory is open to the general public. Agreements have been concluded with several provinces for the exchange of mineral-occurrence information.

The evaluation of fuel resources embraces not only the collection and analysis of existing information but also laboratory and pilot-plant research on fuels. This applies particularly to Canadian coals and their suitability for metallurgical and other uses.

A peculiarity of coal is the difficulty of assessing its properties in the ground or at the mine. Only tests at a pilot-plant scale, e.g., approximating the conditions of actual coal-processing plants, yield reliable information. Samples must be large, which requires considerable effort on the part of the mining companies, especially where work is at the exploration stage. Because of this, the department has endeavored to co-operate with companies conducting exploration work (including established coal producers) in coal evaluation, so as to accumulate a general bank of information.

During the past year, the pilot plants of the department's Metals Reduction and Energy Centre were busy as usual, with coal samples flowing in from the Foothills belt of Alberta and from British Columbia.

Another line of research is based on drilling in Saskatchewan to determine the amount of lignite available for steam raising in thermal power plants. Here, again, the resource cannot be evaluated in the ground, and considerable research will have to be undertaken before reliable analytical results are obtained.

Work proceeded on improving laboratory methods for evaluating the coking quality of western Canadian coals.

The department continued its evaluation of crude oil and a computer program was developed to arrange the oils in ascending order of sulphur content for convenience in resources studies. A spinoff from this type of research has been an analytical procedure to identify the source of spilled oil in lake and sea water.

Mineralogical studies are being carried on to establish the means that could be used for beneficiating various Canadian ores, thus enhancing the nation's resource potential. Among such studies was an extensive survey of the silver-arsenide deposits of the Cobalt-Gowganda area of northern Ontario, which culminated in a recent issue of the *Canadian Mineralogist* devoted entirely to this topic. Also completed were studies of the tungsten-molybdenum-lead-bismuth deposits in the Mount Pleasant area of New Brunswick and of the base-metal deposits in the Red Lake area of northwestern Ontario. Current projects include a study of the porphyry copper-molybdenum deposits in the Highland Valley area of British Columbia and a survey of widely dispersed deposits of low-grade nickel ores in various provinces and territories.

An interesting new study concerns the platinum-mineral deposits from the Tulameen River area of British Columbia; this has resulted in the characterization of little-known platinum minerals and the discovery of two new ones. This work is particularly aimed at increasing our knowledge of Canadian platinum-bearing minerals to a level comparable with that already reached in the Union of South Africa and in the U.S.S.R., both of which exceed Canada in platinum output.

The studies devoted during recent years to the sulphide and related minerals, on which much of Canada's base-metal industry depends, continued throughout the year. A wide range of properties of these natural and related synthetic minerals has been studied with the objective of rendering their beneficiation easier and/or more profitable.

Other mineralogical studies concerned clays and shales from the Atlantic provinces, and their properties during ceramic processing. It was found that these materials contained sufficient kaolinite to make them suitable for the manufacture of structural-clay products. Studies were also made on the properties and usefulness of other non-metallic materials from Canadian deposits, such as silica from New Brunswick, granite, magnesia and limestone from Quebec, tremolite from Ontario, silica from Manitoba, clay-fly mixtures from Alberta, and travertine building stone from British Columbia.

Economic and Social Aspects

ECONOMIC PLANNING AND MARKET ANALYSIS

The growing need in Canada for all forms of energy and the expanding opportunities for sale of energy resources abroad have raised a number of important economic and financial questions. For example, the large capital investment required to develop and bring the various forms of energy to market may put stresses on Canadian financial institutions. Growing national consciousness concerning Canadian ownership and development of energy resources is a crucial factor in energy policy.

Direct investment in Canada's energy industries is already approaching $3.5 billion annually. These expenditures are expected to double by 1980. The implications of these increasing capital requirements must be assessed with great care, and the department is establishing a computerized information-retrieval system and a statistics data bank to analyze the financial moves within the energy industry.

The department will also analyze the implications of the various means available for Canadians to invest in energy companies. Related to this is research on the effect of taxation on company behavior, and the effect of various energy policies on employment.

Oil and Gas

In 1970 Canada attained self-sufficiency in oil, exporting as much oil to the United States from western Canada as she imported from overseas sources into eastern Canada, which area cannot economically be supplied from the Prairie wells. Since 1970 self-sufficiency has been solidified, as exports have increased. The National Oil Policy, which dates from 1961 and establishes the Ottawa Valley as the line dividing the markets for Canadian and imported oil, has been under pressure from petroleum refineries in Quebec and the Atlantic provinces to permit their moving into the lucrative southern Ontario market. This controversial problem has economic, social and strategic implications, that are being assessed by departmental experts. If oil were to be discovered off Canada's east coast, or in the eastern arctic islands, the entire supply pattern would change considerably. Research on the production and marketing of natural gas proceeds parallel with that on oil.

The urgency for such research is exemplified by production figures: in 1960 Canada had a daily consumption of 860,000 barrels of oil; in 1970 the consumption was 1.5 million barrels; in the year 2000 the daily consumption may approach 4 million barrels. In 1960 the country consumed one third of a trillion cubic feet of natural gas; in 1970, one trillion cubic feet; in 2000 consumption could be four trillion cubic feet.

Since all of Canada's exports of oil and gas go to the United States, the department carries out the same type of economic analysis in respect of these exports and related matters as it does for the markets within Canada itself.

Conversely, the oil situation in Canada is always influenced by international developments affecting this

important resource. For this reason, the department keeps track of all world developments in oil and gas. For example, the price increases placed on their oil and gas by Middle Eastern and African nations in 1971 and 1972 have increased the cost of energy in eastern Canada, and they have also raised the question of the reliability of foreign supply. Rising world prices tend to encourage exploitation of the huge resources locked in the Athabasca oil sands.

Other matters which the department has under advisement or in which its experts participate are the proposal to build several new deep-water ports on Canada's eastern seaboard for oil imports and the international consultations dealing with the oil market.

Coal, Uranium and Water Power

The department has initiated studies on which policymakers may base long-term plans for Canada's coal resources. These studies embrace the state of the nation's reserves, and the distribution and marketing factors.

An assessment has been made of the estimated installation rate of nuclear reactors, the types that will be used and fuel they require. One of the questions that may be resolved with the aid of such studies is that of the further processing of uranium, i.e., the so-called enrichment. Since many of the world's reactors will require enriched uranium, which in the non-Communist world is produced in commercial quantities only in the United States, an extensive interdepartmental study was carried out on the feasibility and desirability of building an enrichment plant in Canada.

It was found that such a facility would require an electrical-power source of about two million kilowatts and a capital investment exceeding one billion dollars, exclusive of the power source. Since much of the know-how required for such a plant is in the hands of foreign governments, the Canadian government would have to negotiate for the release of the information and for its safeguarding in Canada. Also, the output from a uranium-enrichment plant would have to be largely exported, since present Canadian reactors are fuelled with natural uranium.

Assessment is also being made of the development in controlled thermonuclear (i.e., hydrogen) fusion, to determine the economic factors governing the use of that potential power source.

Electrical energy has a history of more rapid growth than the growth of energy output as a whole, and this trend will probably continue, with the development of more advanced processes for producing and using electrical energy. However, the construction of power plants—hydroelectric, thermal, or nuclear—often has detrimental consequences for the natural environment, and the choice of power plant will have to take this into account, along with general industrial and economic considerations.

Mineral Commodities

The department has undertaken a broad review of mineral production, trade and consumption in Canada, which takes into account related factors, such as energy, foreign ownership, foreign competition, etc. Federal-provincial consultation on commodity problems, such as those associated with sulphur and potash, also proved useful.

Further processing of minerals in Canada is under review. Generally, the further a mineral commodity is processed in the home country before being exported, the greater the benefit in wages and profits. This principle, however, is affected and sometimes negated by a number of factors.

The department found that further processing of some minerals to the smelting and refining stages has not kept pace with increases in mine production.

Somewhat special is the case of aluminum. Although Canada produces no aluminum ores, it has established a strong extraction industry on the basis of cheap electric power, advanced technology, and well-developed marketing skill. Aluminum has thus become one of Canada's most important export commodities. Since the construction of aluminum smelters is an effective means for regional industrial development, many governments in Europe have offered unusual incentives in the form of grants, low-cost loans and other measures to firms that will undertake to build and operate aluminum smelters in their territories.

The result has been world overcapacity in aluminum production, with a corresponding reduction in the economic advantages of the Canadian smelters. The department is exploring ways and means of reversing this trend, as far as Canada is concerned.

The Mineral Development Sector, which carries out such studies, has begun preparing for the consultations

within the General Agreement on Tariffs and Trade (GATT), scheduled to begin in 1973, and for arrangements affecting supply and demand in the wake of economic realignments, such as the expansion of the European Economic Community. Departmental experts helped to prepare Canadian representations to the International Sulphur Meetings; the OECD Aluminum Study Group; OECD Non-ferrous Metal Statistics Group; the OECD Iron and Steel Study Group; the OECD Coking Coal Study Group; the International Tin Council; the UN International Lead and Zinc Study Group; the UN Iron and Steel Committee meetings; the UNCTAD Iron Ore Meetings; UNCTAD Manganese meetings; the UNCTAD Tungsten meetings; the International Atomic Energy Agency; and the European Nuclear Energy Agency.

The department also organized and hosted a tour for mining and metallurgical experts from the People's Republic of China.

Certain mineral commodities received special attention from departmental analysts. These were sulphur, potash, aluminum, and copper.

An interdepartmental study group was set up to investigate means whereby a normal pattern could be maintained in copper distribution. Contractual arrangements on copper between Canada and Japan were also examined. Most of the copper ore produced in western Canada is exported to Japan in the form of concentrates, as it is Japanese industrial policy to import raw materials and to export finished products. This policy did have the effect of establishing a modern copper-mining industry in western Canada. However, Japanese smelters have recently endeavored to pass on certain new costs to Canadian copper exporters, costs arising from the devaluation of the Japanese currency, stricter pollution-control measures in Japan, and reduction in the imports contracted for. The department investigated the nature and the impact of these requests.

Both the federal and the British Columbia governments believe that copper smelting in that province is economically viable. The selection of a smelter site, however, is a lengthy and complex process, based on transportation costs, access to markets, ore supply, tax treatment in various countries, etc. Another complication is the air and water pollution a smelter is likely to cause. Smelting techniques and the cost and means of pollution abatement have also to be considered.

World oversupply in sulphur and the "involuntary" production in Alberta has resulted in the accumulation of unsaleable stockpiles. Federal-provincial discussions and international meetings are aimed at resolving this oversupply problem.

In Saskatchewan the provincial government has taken measures intended to regulate the production and marketing of potash, whose production in that province has far outstripped demand.

A number of studies concerned markets for Canadian minerals and strategies that might help to expand them, and the technical and commercial feasibility of proposed new mines and processing plants.

Growing public concern over the environmental effects of mineral development has directed the attention of departmental experts to the economic effects of such pressures. It is undeniable that greater safeguards for the conservation of the environment make mineral exploitation and processing more expensive. This, in turn, may lead to a weakening of Canada's competitive position in world mineral markets, especially in relation to other nations with less stringent environmental safeguards. It is the desire of economic and engineering experts to combine, as far as possible, better environmental safeguards with increasing productive efficiency.

Among the subjects studied this year were sulphur-dioxide emission and pollution, health hazards in the use of asbestos, and submissions to be made to the Stockholm Conference on the Environment.

Another field of study was systems analysis for use in the Canadian mineral industry.

The social and economic distress usually caused by the closure of mines in communities where these mines were the main source of income has prompted the department to search for ways of mitigating such effects. Mine closures may be due to absolute exhaustion of ore, technological change, or poor markets for the mine product. Better planning and co-operation between the various levels of government and the mines are most important.

During the period under review, the most significant event in the field of corporate taxation in Canada was

the passage of a revised federal income-tax act. The new act has far-ranging implications for Canada's mining industry, inasmuch as it reduces some of the tax exemptions for new mining ventures. The Mineral Resources Branch of the department participated in drafting the act and the proposed regulations, in so far as these concerned mining and petroleum production. One of the tasks of the branch during the review period was to ensure that the proposed new income-tax rules were properly understood by provincial governments and private industry.

The branch continued to advise other federal departments on specific taxation matters affecting some Canadian mines. It also provided foreign governments with information on Canadian mining laws.

REGIONAL AND SPECIAL PROGRAMS

Under this heading, the department reports chiefly on activities designed to benefit certain Canadian regions that are in need of economic development or that merit special research because of their peculiar geography. Also dealt with are foreign-aid projects.

Petroleum and Other Energy Sources

The Task Force on Northern Oil Development, chaired by the deputy minister of the department, was established by the federal government in December 1968 as an interdepartmental co-ordinating and advisory group on all matters relative to oil and gas development in the Canadian north.

Initial guidelines resulting from the work of the Task Force were issued in August 1970. Draft environmental and social guidelines were scheduled for release in mid-1972; these were based on three years of field and laboratory studies. The Task Force is also working on guidelines concerned with the financing, ownership and Canadian content of northern pipelines.

In 1968 the federal government and a number of companies formed Panarctic Oils Ltd. The government has maintained an interest of 45 per cent in the company and is determined to keep it in Canadian hands. The company is exploring for oil and gas in the arctic islands and has had encouraging showings. This work will be important in the determination of the oil and gas potential in the Arctic.

During the year the department helped the Cape Breton Development Corporation to conduct a technical-economic feasibility study of several choices open for the Number-20 Colliery of that corporation. The department co-operated with the Department of Mines of Nova Scotia and the Pictou County Research and Development Commission on a provincial plan for the orderly closure of the McBean Mine in Pictou County. The contribution of the department was financial and technological. The same type of aid was rendered to the New Brunswick government in its efforts to rationalize the province's coal mines.

The uranium industry also continued to require government assistance. Denison Mines, Canada's major uranium producer, and the federal government joined in stockpiling uranium in 1971 at a rate of two million pounds of uranium oxide per year. The agreement expires in 1974. Uranium Canada, a Crown corporation, was formed as an intermediary between Canada and Denison Mines, and the company is acting as sales agent for the stockpile. A tentative agreement was reached with Spanish utilities to purchase the joint stockpile over the next several years.

Federal-Provincial Co-operation

The department, through its Energy Sector, participated in the Columbia River Treaty Permanent Engineering Board, the recently established water boards for the two northern territories, the review board established under the Nelson River Transmission agreement with Manitoba, the study board examining the effects of the Lake Winnipeg-Churchill and Nelson River developments, and the Ontario Advisory Committee on Energy. Close liaison has been established with Quebec's James Bay Development Corporation, the James Bay Energy Corporation and Hydro Quebec.

The Energy Sector took part in a government-financed study of the socio-economic impact of the offshore exploration for oil and gas on the Atlantic provinces as well as the impact that might result from oil production in the offshore. The exploration now going on has already benefited Atlantic shipyards. The sector also continued its liaison with the Maritime utilities concerning the strengthening of electrical interconnections and the feasibility of power from the tides of the Bay of Fundy.

The federal government, through EMR and the Department of Regional Economic Expansion, has made

agreements with Manitoba, Quebec, New Brunswick, and Newfoundland and Labrador whereby it will help to finance mineral development in those provinces, some of whose regions are economically depressed.

In New Brunswick, work was undertaken in accordance with a 1970 agreement between the federal government and the New Brunswick Department of Natural Resources. This work has generated new information on the mineral potential of the province through geophysical and geological surveys. Test drilling in the Moncton-Saint John sedimentary basin indicated large deposits of salt and also of potash. Both are of potential economic significance. The salt may form a basis for an eventual chemical industry in that region, and the potash is close to the major market in the northeastern United States. These finds have attracted much interest in the mineral industry, and the province is now evaluating development proposals from a large number of companies. A second agreement for furthering mineral development was in the final stages of negotiation.

The Canada-Newfoundland agreement for mineral development will cost $2.7 million over four years. The money is being channelled through EMR and DREE.

In September 1971 the governments of Canada and Quebec completed renegotiation of a 1968 agreement for the Gaspé area, extending the original period from five to eight years and increasing the budget by $152 million to $411 million. Both mineral development and the transportation and social infrastructure are to be improved. Another agreement, for the expenditure of $20 million over five years, covers the northwestern part of the province and the Lake St. John area.

The Geological Survey of Canada has been responsible for the implementation of the federal-provincial aeromagnetic surveys. During 1971–72, two major contract surveys covering about 40,000 square miles were completed, one in Newfoundland and the other in central Baffin Island. About 115,000 square miles were mapped under contract in British Columbia, District of Mackenzie and in Quebec.

Assistance to Gold Mines

The Emergency Gold Mining Assistance Act (EGMA), which was passed in 1948, has provided financial assistance to gold mines suffering from the effects of rising production costs and an artificially fixed price for gold. This enabled the mines to stay in business and thus to provide a livelihood to the gold-mining communities, mostly in northern Ontario and Quebec. Even with this financial aid, many gold mines have ceased operating, and the number of lode gold mines receiving assistance under the act declined from 87 in 1948 to 28 in 1971.

In late 1971 a dramatic change occurred in the gold market that gave a new lease on life to the gold mines. The price of gold in open markets suddenly rose to $44 per ounce at the end of 1971 and to $48 per ounce in March 1972. This made it more profitable for Canadian gold mines to sell their output in the open market and thus to forego the EGMA aid, which was tied to the provision that the production be sold to the Canadian Mint. If the open-market price continues to be high, the prospects for the survival of Canadian gold mines are good, and new gold mines may be started.

Assistance under EGMA has been contingent on inspection of mines by engineers of EMR's Mineral Development Sector. Maximum assistance is $10.27 per ounce of gold produced. From 1948 to 1971, inclusive, payments totalled $301,270,629. During 1971 alone, payments amounted to approximately $11.8 million—down from $13.7 million the year before.

An amendment to EGMA enacted in February 1971 made it mandatory for mines receiving assistance to give notice of closure at least four months in advance, to use the services of the Department of Manpower and Immigration in hiring of new employees and in the placement of employees idled by mine closures. The amendment also extended the life of EGMA to June 30, 1973.

Foreign Aid

Resource development in developing foreign countries is one of the aims of Canadian foreign assistance dispensed under the auspices of the Canadian International Development Agency (CIDA). Of the $300 million allocated to foreign aid by CIDA in 1971-72, approximately five to six million dollars was destined to resource development. The Department of Energy, Mines and Resources plays a significant part in channelling this type of aid.

Practical training in many aspects of the earth sciences is given to some candidates from developing countries. These candidates may be supported either by CIDA or by an agency of the United Nations. Several EMR

experts are sent abroad each year as technical advisers. Also, capital assistance, primarily in mapping and geological surveying, is planned and supervised by EMR personnel.

Two technical-assistance projects were started during the year—a copper-mining project in India, and a lead-silver prospect in Burma. The department recommended that two mining experts be provided to India, and that a geologist, diamond-drilling supervisors and two diamond drills be provided to Burma. Assistance was rendered in the recruitment of qualified personnel.

Departmental experts from the Geological Survey of Canada supervised aeromagnetic survey contracts on behalf of CIDA in various West African countries and in Guyana.

Much time was spent in late 1971 in preparation for the second session of the United Nations Committee on Natural Resources, which is sponsored by the U.N. Economic and Social Council. The session was held in February and March 1972 at Nairobi, Kenya. The Canadian delegation was headed by J. P. Drolet, assistant deputy minister (mineral development) of EMR.

Technology and Environmental Concerns

TECHNOLOGY

A large share of the research carried out by the department is aimed at increasing the level of technological effectiveness in Canada. Because of EMR's mandate in the field of non-renewable resources, such research is concerned chiefly with mine safety, the concentration and beneficiation of ores, the processing of fuels to a marketable state, metallurgy, the methodology and instrumentation used in various geological, geophysical and topographic surveys, etc. Every year, Canadian companies active in the resource field benefit from technological advances produced by EMR research, and the work of the department itself progresses through continuous innovation.

Patterns in Fuel Technology

The department, through its Energy Development Sector, is co-operating with the Science Council of Canada in considering the kind of research that would contribute to the conservation and more effective use of energy sources.

Not all of Canada's coal deposits can be mined economically and safely with existing technology, especially where thick coal seams dip steeply. Techniques used for similar seams in other coal-producing nations are being examined to determine whether they can be applied in Canada. The transportation of coal, a bulk material of low unit value, has always been a problem in Canada, where coal fields are often far from industrial markets or export points. The department has been co-operating with the railways, coal producers and coal consumers in reviewing transport systems, including unit trains and pipelines.

The design and operating characteristics of Canadian nuclear reactors have also come under departmental scrutiny. The excellent performance of the first three Pickering reactors has rebutted many critics of the Canadian design, which uses natural rather than enriched uranium as reactor fuel. Analyses have indicated that it would be premature to embark on any substantial research to develop fast-breeder or thermonuclear reactors.

To keep Canada in the forefront on electrical technology, substantial capital support is being given to the Hydro Quebec Research Institute, whose research projects are reviewed by an advisory committee with departmental representation.

Stringent safeguards have been developed for offshore exploration for petroleum, aimed at preserving the ocean environment from contamination. The expanding exploration activities also encourage the companies concerned to develop new technology. The drilling units, among the largest in the world, now cost $25 million each to build and $40,000 per day to operate. The department, through its Resource Management and Conservation Branch, exercises considerable influence on the design of these units and of other exploration equipment.

Automation and Surveying and Instrumentation

The Surveys and Mapping Branch made a start in the development of a data bank of geodetic-control surveys. Electronic development was completed on three projects concerned with the automation of surveying procedures.

Several studies will have a profound impact on departmental mapping. A computer program purchased from the University of Stuttgart was tested for use in adjusting large photogrammetric blocks. This program can accommodate a wide range of ground-control configurations, with a minimum of control points. Operational procedures and specifications are being designed and documented to use this program in production.

A second program, which involves the completion of a photogrammetric adjustment method, contains many features peculiarly suited to the Canadian geography and is therefore potentially attractive to Canadian mapping companies.

Two months of geological surveys in various parts of the Canadian Shield were devoted to experimental/airborne gamma-ray spectrometry surveys. In addition to providing data useful to resource discovery, the results of this work will lead to improvements in equipment and techniques.

Geologists studied the electrical properties of rocks and sought to improve the instrumentation involved. Preparations were made for testing the use of seismic methods in defining the location, shape and size of sulphide orebodies. Other technological studies concerned airborne magnetometry and color photography as aids to geological mapping.

The Earth Physics Branch has equipped six of its magnetic observatories with automatic recording devices, eliminating the need for daily attention by a skilled operator. This system is now being tested.

An improved calibrator for meters measuring earth tides (movements of the earth's solid mass analogous to ocean tides) was built by the staff of the Gravity Division and is now being tested.

Metallurgical Technology

The Physical Metallurgy Division has developed great expertise in dealing with molten and solid metals, both alloyed and unalloyed. This research on melting, casting, and performance of metals has enlarged and improved Canadian technology in these fields.

One type concerns the behavior of molten metal in moulds. This is studied with X-ray fluoroscoping equipment, movie films, and fluidity tests. It is possible to produce alloys which, when exposed to certain temperatures and loading conditions, can be stretched by as much as 25 to 50 times their original size. Such alloys are said to be superplastic.

The department's metallurgists are studying the feasibility of producing zinc-aluminum alloy forgings by this method, which can produce very complex shapes by low loads. The main drawback is the slowness of the process.

The phenomenon of superplasticity in steel is also being studied, with the use of various thermomechanical treatments to obtain the best superplastic properties.

A very specialized project is the development of a new surgical needle. In microsurgery on small blood vessels it has been found that available needle-suture combinations are too large to avoid considerable tissue damage, which may lead to thrombosis. The physical metallurgists have made needles of significantly smaller diameter from unconventional metals and alloys of exceptionally high strength and flexural rigidity. Initial tests on laboratory animals have proved successful. Experimental needle-suture combinations have been prepared by electro-polishing and by laser welding for more extensive tests.

Work is continuing on the evaluation of the susceptibility of high-strength alloys to crack from environmental effects.

The addition of very small amounts of rare-earth metals, such as cerium, to structural steel can effect a great improvement in the rolling properties of steel. This, too, is being studied.

The development of titanium alloys containing aluminum has been retarded because when aluminum content is too high, the steel shows poor ductility and is susceptible to cracking. Research has shown that by substituting gallium for some of the aluminum an experimental alloy can be produced with considerable ductility and no loss of strength. These experiments have aroused considerable interest among metallurgical investigators generally.

Pipeline construction in Canada may benefit from current tests for defining the resistance of steels to sudden stress ("dynamic fracture toughness").

EMR's Physical Metallurgy Division acts as examining authority on behalf of the Canadian Government Specification Board for certification of personnel for non-destructive testing. Since the inception of these examinations eleven years ago, 2,300 persons have been examined, 22 per cent of them during the past year. Tests were held in eleven centres across Canada.

Petroleum Technology

As Canada's demand for petroleum products increases, there is a growing need for exploitation of lower-grade crudes. The work of the Fuels Research Centre has therefore focused on beneficiating low-grade petroleum, which has a high sulphur and a low hydrogen content. A method was found to increase the yield from Athabasca bitumen by two per cent—a significant amount in terms of annual production. Work was also done on improving catalysts used in petroleum refining.

Since natural gas is in ever shorter supply, an engineering study was made of other sources for the production of carbon black. Results are not yet complete.

The growing concern over the adequacy of Canada's petroleum resources in the face of expected future demands has prompted research into the incorporation of petroleum in coal as a means of stretching available petroleum resources. The difficulties in manufacturing, transporting and storing such slurries are numerous. It was found that acceptable flames could be produced with coal-in-oil mixtures, but that combustion rates of the various coal components varied widely. This requires further study.

Mine Design

Better design of mines, both underground and open pit, is aimed at improving safety and extraction rates.

Approximately 300 million tons of waste rock and 300 million tons of ore are being mined annually from open pits in Canada. If the rock slopes forming the walls of these large excavations could be designed with the same degree of accuracy as soil slopes, and if support systems could be developed comparable to those used for underground excavations, waste volumes could ultimately be reduced, resulting in substantial economic savings. Funds are being used to expand research in this area through outside contracts to universities, consultants and companies. The objectives of this project are to develop: design systems suitable for open-pit rock slopes, artificial support systems for open-pit rock slopes, and reclamation procedures for waste embankments.

A series of tasks is to be completed within the next three years, so that in the fourth year an engineering handbook on designing pit walls can be drafted for the use of staff engineers on mining properties. The task areas are as follows: (a) groundwater pre-mining survey, operations monitoring and controlling; (b) blasting effects and design; (c) structural surveying and analysis; (d) testing for field properties; (e) monitoring of effects of excavation, and (f) design analyses including both technological and economic data. The work in task areas (a) to (e) is being done on contract by universities and consultants with some assistance on instrumentation by Mines Branch staff; (f) will be done by Mines Branch staff.

Full-scale trials of artificial support for slopes are to be initiated in different rock types so that the effects of variations of geology and rock properties can be evaluated. Two contracts have been let to mining companies, with associated consultants, to conduct these trials.

The first phase of the reclamation work has been the production of *Tentative Design Guide for Mine Waste Embankments in Canada*. Work is continuing in co-operation with the Extraction Metallurgy Division on the effects of current operations on water quality, on alternate land use, and on the probability of public hazards. Vegetation studies are being done at Elliot Lake and, through the co-operation of the Department of Agriculture, at the Soil Research Institute, Ottawa.

By following the handbook on design produced by this project, waste volumes should be ultimately reduced by more than 25 million tons per year, representing a saving of more than $12 million annually. In addition to the monetary benefits, regions should benefit socially from the expanded production. Throughout the national economy other industries should benefit from the technological fallout, e.g., in the construction of highway and dam excavations.

Underground metalliferous and industrial mineral mines continue to be the backbone of mining in Canada. Research in these mines is concerned mainly with arti-

ficial support systems to improve the proportion of the resource that can be extracted. Civil-engineering techniques of cable bolting are being tested in connection with roof stability. Cut-and-fill is the most common mining method, and the stabilizing effect of back-fill is being assessed.

Work is proceeding on the development of advanced mining technology, which, while preserving the environment, will also lead to a greater utilization of mineral and energy reserves and to an improvement in Canadian mining techniques and management.

Another project is concerned with determining the best extraction ratio for salt mines. It was found that by leaving natural pillars of different design salt mines could obtain much higher extraction rates without impairing roof stability.

Ore Treatment

"Hydrometallurgy" is that branch of ore processing which uses liquids rather than heat to separate metals and gangue. Leaching is an important hydrometallurgical method.

One of the methods studied by the department in this field is percolation leaching of lump sulphide ores with bacterial solutions. Earlier work both in the laboratory and at the uranium mines had shown that such methods can be used on certain sulphide-bearing uranium ores in the mine itself, resulting in lower costs and less damage to the environment, because less material is brought to the surface. During the past year, preliminary work on copper-nickel sulphide ores has shown that the technique has possibilities for certain of these ores, though leach rates would be lower.

Acid pressure leaching of nickel-copper sulphide concentrates in a stirred reactor has also been studied, and has shown promising results. One of the benefits is the recovery of sulphur in the elemental form, which again reduces environmental damage.

Mathematical modelling, though widely used in industrial practice, has not yet found much application in metallurgy. The department is carrying out studies on ways of raising extraction efficiency with the use of generally applicable mathematical models.

The provision of technical evaluation, advice and background information on non-ferrous extraction metallurgy to private industry and other government departments has been an important function of the Extraction Metallurgy Division. This has included support of several co-operative EMR-industry groups formed for the exchange of information.

In its laboratories, the division is developing corrosion-resistant coatings for steel that will give a longer life to mill equipment, such as flotation cells and ball mills. Electroplating has produced chromium coatings with superior corrosion resistance. Other studies concerned new applications of X-ray emission spectroscopy, determination of organic reagents used in solvent extraction for metal recovery, and the automation of laboratory procedures.

To further the standards of analytical chemistry in Canada, the department is collaborating with the Canadian Mineral Analysts in the compilation of a *Canadian Assay Manual;* the first installment was scheduled to appear in mid-1972.

"Flotation" is the separation of the metal in pulverized ores from waste material by the use of solutions that will cause the metal particles to float above the waste. Flotation research is an important function of the Mineral Processing Division.

Among the various methods investigated were the concentration of metallic ions in flotation pulp, measurements of electric charges on flotation bubbles, filter cloths used in industrial plants and the electrochemistry of filtration, and development of a reagent to selectively float wolframite in tungsten ores that may lead to better recovery of wolframite.

The department has developed a process to selectively float antimony sulphides. Flotation of antimony ores is a recent development; former sources of antimony were lump ores from the Far East. Two Canadian mines now use flotation, but their process is not very efficient. A patent application for the EMR process is pending.

Continued research on recovering iron previously discarded in tailings has produced methods now being applied to the tailings from Carol Lake and to the "treat-rock" discarded mine waste at Schefferville. Departmental experts are co-operating with the company in the final phases of flotation research on the Schefferville ore in preparation for putting the new flotation plant in operation. Completion of these proj-

ects will materially increase the use of the orebodies concerned and thus conserve Canada's iron resources.

Many Canadian reserves of iron ore contain sulphides in such proportions as to prevent their exploitation, especially with present stringent anti-pollution regulations. Research has been completed on the flotation of pyrite from an iron-carbonate ore that will make possible the continued operation of a company's sintering plant; also, a flotation method has been developed for removing sulphides from iron ore produced by a potential iron mine. A copper concentrate is a valuable by-product.

Laboratory research in co-operation with private research has resulted in the development of treatment methods for a large complex sulphide-oxide orebody in New Brunswick with the recovery of lead, zinc, tin, tungsten, molybdenum, bismuth and fluorite. Pilot-plant studies have confirmed the metallurgical results, and feasibility studies are now being carried out by the company.

Studies on the development of technology for new techniques and processes for the beneficiation of Canadian industrial minerals were carried out on fluorite-barite and celestite from Nova Scotia; beryl spodumene and graphite from Quebec; ultrabasic rock, kaolin and tremolite from Ontario; spodumene from Manitoba; marl from Saskatchewan; magnesite from British Columbia; and scheelite from the Northwest Territories. Of particular interest has been work on the floatability of celestite in which the effectiveness of new taurates as collectors at various concentrations and low temperatures was investigated. Comparative grinding trials were carried out on 20 non-metallic minerals.

Much of the research in the Mines Branch is concerned with more fundamental studies into the structure of metal-bearing and other useful minerals. This includes the development of standards for the uniform assessment of minerals. In the analytical field, the department participates in the development of nationally and internationally acceptable methods of analysis for metallic constituents in ores, minerals, alloys, etc., on behalf of various standards associations. A range of standard reference ore minerals, typical of mineral deposits across Canada, is being developed. Statistical treatment of analytical results is being developed in co-operation with other agencies.

Another important field, whose results are of immediate interest to producers, is the on-stream analysis of ore slurries. A pilot plant has been developed for on-stream slurry analysis as an aid in process control in mills, with the use of X-ray fluorescence. A Canadian company has undertaken to develop an X-ray fluorescence unit based on this pilot plant. Other methods for characterizing slurries are also being studied, including the use of radio-isotopes for exciting the X-rays from the two or more elements to be determined.

Studies continued on means of producing new aggregates for construction and on the improvement of the quality of existing construction materials of mineral origin. Experimental concrete and cement mixes were subjected to various tests, including the effect of adverse environmental conditions on the test specimens.

Coal-Processing Technology

Canadian coal is staging a remarkable comeback after two decades of relative eclipse. However, modern ferrous metallurgy and combustion technology often require considerable processing of coal before use, which places a research burden on Canadian coal mines.

Substantial progress was made during the year in modern coking technology, especially in the field of form-coking processes. It has been found that recycling the coke breeze, which reduces the amount of low volatile coke in the oven charge, yields more coke. Two Canadian steel plants are now carrying out commercial trials of this process, and a third plant is considering experiments.

Research and development on coal washing continued at the Western Regional Laboratory in Edmonton. Consolidation of the coal-processing plant (with a capacity of three to eight tons per hour) progressed satisfactorily. The reconstitution plant for pipeline-sized coking coal, which used oil-agglomeration technology, was adapted to the dewatering of typical coal products and recovery of plant water. The coal-processing plant has become identified with the name "EMR Process," which designates the design and operation of its particular coal-washing circuit. A plant using the process is under construction at a mine in western Canada.

A two-year $511,000 program is under way to find economic ways of reducing the sulphur content in Cape

Breton coal. This research is being undertaken in aid of the Cape Breton Development Corporation which is seeking to produce coking coal at its new Lingan mine near Sydney, N.S. Information gained from the work at the Lingan pilot plant could also be applied to treatment of coal waste from mines at Springhill, N.S., and in New Brunswick.

Special attention is being paid to the so-called "combined-cycle" system of power generation which is now being developed extensively in the United States, Germany and elsewhere. In this system, which many experts believe will be the basis of a new type of thermal power plant, the fuel is turned into gas by air and steam pressure. The pressurized gas, after purification, is used first in gas turbines and the waste heat is then conducted to steam boilers which power steam turbines. The method has the advantages of lower capital costs and higher operating efficiency. Sulphur control is achieved more easily by this method than in other processes, so that air pollution is reduced.

Several types of Canadian coal may be suitable for this new combustion system. Also, coal-in-oil slurries might be used, which would encourage the movement of cheap strip coals from the Prairies to Ontario in slurry pipelines. Studies of these technological possibilities continue.

Development of Equipment and Instrumentation

Much of the work described in the foregoing sections would be impossible were it not for the development of specialized equipment and instrumentation in the technical services shops of the department itself. Often such equipment cannot be obtained on the market; also, available equipment requires adaptation, modification and installation before it can be put to use.

One of the most important tasks in 1971–72 was the equipping of the coal-research laboratories on Corkstown Road, west of Ottawa. Among the equipment designed and built by technical services staff was a coal-crushing station with vibratory sorter, a unit that splits up coal samples in such a way that several portions will be identical in every way; a "dry" coal quencher that uses water jackets instead of a stream of water; and a special door-lifting mechanism for the twelve-inch coke oven.

In conjunction with personnel of the Explosives Division, a door and a door lock for explosives magazines was designed. The drawings that were produced for this equipment have been incorporated in the EMR publication *Standard for Blasting—Explosives Magazines*. The new design meets more stringent safety standards. A number of models of the door lock were made for purposes of demonstration, and one has been given to each area inspector of explosives.

The staff built a machine for testing tear strength of materials from existing specifications.

Installation and distribution of electrical power circuits in the Mines Branch plants were also in the hands of technical service staff. A test facility for diesel engines was designed and installed under contract by the Department of Public Works.

REMOTE SENSING

The remote-sensing activities of the department are concerned with the scanning of Canada's land and water areas from aircraft and satellites and the development of the necessary technology.

Aerial survey and air photography have long played an important part in mapping Canada's territory and in helping to assess various resources, such as forest cover, agricultural crops, wildlife, etc. The development of sophisticated cameras and films—especially various types of infrared films and filters—as well as other types of sensors, and the possibility of placing such sensors in high-flying aircraft and in orbiting satellites has opened a new era in the mapping and evaluation of the Canadian environment.

Although remote-sensing techniques had been used for some time by various government and private agencies in Canada, the national effort in this field did not receive central co-ordination and planning until early 1971, with the establishment of the Canada Centre for Remote Sensing as a branch of EMR.

In May 1971 an agreement was signed between EMR and the U.S. National Aeronautics and Space Administration (NASA) whereby Canada would receive remote-sensing imagery from an orbiting satellite that was to be launched by the U.S. agency in 1972. At the same time, the Department of National Defence agreed to supply aircraft, crew and maintenance for airborne remote sensing under contract to EMR.

The cabinet approved a supplementary budget in July to increase the capacity of the Air Photo Production Unit and the National Air Photo Library, a budget for the remote-sensing program (airborne and satellite), and the establishment of the new Interagency Committee on Remote Sensing. In January 1972 that committee approved the terms of reference of the Canadian Advisory Committee on Remote Sensing, which consists of members from various levels of provincial and federal and private research establishments.

The Prince Albert Satellite Station (formerly known as the Prince Albert Radar Station) was completely refurbished to allow its use for the reception and recording of data from the Earth Resources Technology Satellite (ERTS), which was to be launched by (NASA) in July 1972. This work involved replacement of the antenna feed and tracking systems for the 85-foot-dish antenna, installation of new receivers and special recording equipment. A "quick-look" system producing instant photographs of the imagery flowing in was included in the system.

At the same time, the Ground Data Handling Centre was built up in Ottawa, containing the computers and other devices for transforming the tapes of ERTS imagery flown in from Prince Albert into corrected photographic film.

Airborne remote-sensing projects were flown for investigators in federal and provincial governments, universities and private industry. All these projects involve extensive ground-truth investigations, which are conducted by the principal investigators. Much of the data thus acquired will be used in evaluations of ERTS imagery.

Flying was carried out with one CF-100 and one C-47 aircraft; 28,000 sensor line-miles were logged. A Falcon aircraft, completely equipped for remote sensing, was purchased in January 1972. It will be serviced, maintained and operated by DND crews. A second DND-owned C-47 was obtained in the fall of 1971. A considerable number of man-hours were expended in the design of the most desirable configuration of this aircraft and the type of sensor package it will carry.

The Canada Department of Agriculture and the Forest Management Institute of the Department of the Environment have continued to make heavy demands on airborne sensing. The International Year on the Great Lakes created a demand for a number of preliminary investigative flights, necessitating a large portion of winter flying.

The sensor-development program, now in its second year, is being directed toward better ways of detecting air and water pollution, the physical properties of sea ice and improved methods of surveying Canada's natural resources. Competent sensor-development groups in industry, university and government were approached to undertake specific projects that were conceived from the wide range of requirements laid down by the user working groups of the Canadian Advisory Committee on Remote Sensing.

In air pollution, a laser ranging device know as a Lidar has been operated at York University to measure atmospheric constituents over the city of Toronto. Barringer Research Ltd. has tested a remote sensor for use in air-pollution monitoring over the Yellowknife region. Other air-pollution systems have been studied.

Water-pollution instrumentation includes a laser fluorosensor, developed by the University of Toronto Institute for Aerospace Studies, that was tested on the ground with the use of a trailer installation located at high vantage points. When the laser is pointed at the water surface pollutants such as oil slicks fluoresce. The fluorescent radiation is detected by a suitable sensor boresighted with the laser. Such an instrument can also be used to trace harmless fluorescent dyes introduced into streams and industrial-waste systems for tracking plumes and identifying polluters. Another system, developed by Spar Aerospace Products Ltd., uses an image-dissecting camera for tracking algae growths and other manifestations of pollution in the Great Lakes. It relies on the spectral signature and thus should find a wide range of uses in resource surveillance as well. Flight trials are planned for 1972–73.

An entirely new principle is being exploited for measuring the thickness of sea ice. Developed by members of the Department of Electrical Engineering, University of Toronto, the instrument uses the optical principle of holography in the microwave region to measure ice thickness and other physical characteristics. The Holographic Ice Survey System, known as the HISS radar, has been tested in a helicopter in the Toronto area, but will be tested in the Canadian Arctic in the winter of 1972–73.

An important event in the field of remote sensing was the First Canadian Symposium on Remote Sensing, held

in Ottawa in early February 1972. This symposium was attended by about 500 delegates from all parts of Canada who listened to over 60 scientific papers on all aspects of this burgeoning new branch of science.

ENVIRONMENTAL CONCERNS

While a concern for the preservation of the natural environment and the conservation of non-renewable resources permeates most of the activities of the department, certain research projects are dedicated exclusively to these principles. For example, the manner in which Canada's energy potential is being used will have a profound effect on the environment. Electrical energy is generally regarded as "clean," especially in comparison with coal and oil; but it must be remembered that electrical energy is not found in nature as a ready resource but must first be generated, either by harnessing water power or by the combustion of fuel. All fuel, including uranium, discharges heat into the environment, such as the lakes and rivers whose water is used for steam cooling, and this causes what is known as "thermal pollution." Aware of the problem, the department, in close conjunction with the electrical-power companies, is carrying out an assessment study of such dangers.

Again, the exploration for petroleum and natural gas which is now taking place off the east and west coasts of Canada carries with it the well-documented danger that the fragile marine environment may be polluted by oil spills and that the activity itself may disturb the ecological balance. To counter such dangers, the department's Resource Management and Conservation Branch, which exercises jurisdiction over offshore exploration, has laid down stringent safeguards under which exploration teams must operate.

Terrain Protection

Comprehensive studies of the terrain—and especially the soil—have only recently been recognized by industrial and urban planners as a prerequisite to responsible development. The need is particularly acute, as in Canada many soils either are of the alluvial type or are subject to severe frost effects, including permafrost.

The Terrain Sciences Division of the Geological Survey of Canada has embarked on an ambitious program of such studies, both in the inhabited and uninhabited parts of the country. The urban terrain was studied with the aid of borehole records from 27 cities. Data from 110,000 borehole records are now available for all major Canadian cities; these will be of great assistance in urban planning. This study, which was carried out almost entirely under contract, involved over 430 persons and 1,173 man-months.

In the Arctic, the Mackenzie Valley has attracted the concern of conservationists because of planned road and pipeline construction. To gain a better knowledge of that terrain, geologists are mapping 40 map-areas; during 1971 field work was completed on 26 of these. Field work was also carried out to determine the engineering-geological characteristics of earth materials and to evaluate factors affecting terrain performance. A field laboratory in engineering geology was set up at Fort Good Hope. Geologists also described and interpreted landforms in the Mackenzie Valley and the behavior of permafrost.

Construction of the new Montreal International Airport at Ste. Scholastique, Que., is requiring much geological information, and geologists have established a project to map, describe and explain the surficial deposits and landforms, to investigate the geodynamic processes and to determine the bedrock configuration beneath the area. These data will be valuable in planning for engineering construction, industrial development and land use, agriculture, and water supply.

The disastrous landslide at St. Jean Vianney, Que., in May 1971 prompted a request from the government of Quebec for engineering-geological assistance, and officers of the Geological Survey and the National Research Council participated in an on-site study as well as in an evaluation of proposed remedial measures.

Increasing urbanization in Canada will make effective urban land use of great importance. A prototype study initiated in 1970 in the Ottawa-Hull area (where field costs would be minimal and the program could be carried out by staff in conjunction with other duties) was continued in 1971. The purpose of this study is to develop methods of compiling, evaluating and presenting geological information for the areas to meet the needs of engineering and planning. This is being accomplished by preparing a comprehensive data base which will illustrate distribution, thickness and physical properties of surficial and bedrock materials and the magnitude and effect of active geological processes.

The program will allow six types of maps to be produced: bedrock topography, drift thickness, water-table elevation, distribution of surface material, and two types of proximal maps in which distribution of up to ten types of materials can be plotted by symbol. The importance of this type of information for regional planning in urban areas is obvious, especially for those charged with long-term planning.

Studies similar in aim but less comprehensive were carried out near Tuktoyaktuk, District of Mackenzie. Particular emphasis was given to the location of aggregate, and two areas of gravel suitable for construction uses were found. The data obtained during the study should prove valuable in planning future expansion of this far northern coastal settlement.

It has long been known that certain marine clays deposited along the St. Lawrence and Ottawa valleys during Champlain Sea time are unstable and prone to landslides. In mid-August a preliminary study, designed to identify some of the parameters significant to delimiting these deposits, was begun in co-operation with the Quebec Department of Natural Resources. Initial studies were made in the Gatineau River valley; these will eventually be extended to general landslide problems in eastern Canada.

Mapping of the surficial deposits of the Winnipeg area was completed. This study was designed to map, describe and explain the Quaternary deposits and landforms, to provide areal information and also background information applicable to soils and mapping, engineering and groundwater in this region, which includes one of Canada's major urban areas.

A study of the Quaternary geology of the Bow River valley was completed. The main object of this study is to produce a surficial map of the Calgary area that will complement subsurface data obtained from a drilling and well-logging program carried out in 1967 and 1968. The two sets of data will form a valuable basis for engineering-geology studies in the Calgary area.

A study of natural slope stability in the Fraser Canyon area of British Columbia was commenced during the report period. The area was selected on the basis of abundance of known slides and their danger to transportation routes, hydroelectric transmission lines and inhabited areas. Eighteen slides were mapped and the results obtained will permit a better assessment of remedial measures.

The Canadian standard seismic network, consisting of 23 observatories widely distributed throughout Canada and equipped with short- and long-period seismographs, continued in operation. The additional network, which gives better coverage of local earthquakes in earthquake-prone areas of Canada, was strengthened by the opening of an electronic regional station at Whitehorse, Y.T., in order to improve knowledge of the seismicity of the Mackenzie Valley and potential pipeline routes.

General and specific studies of Canadian seismicity continued. The country-wide results for 1966 were sent to press—about 400 Canadian earthquakes were detected, located and their focal parameters determined. The continuing study of Canadian seismicity was, however, further delayed by a concentrated effort on a study of the seismicity of potential pipeline routes to the western Arctic. Much technical information was made available to the interested consortia, and a start made on a major report summarizing all available information and calculations.

A number of very important papers were published in the continuing research and development program into the detection, location and identification of underground nuclear explosions. The division assisted External Affairs in the preparation of working papers for the Conference of the Committee on Disarmament and in their presentation. This work continued to attract favorable attention around the world and evoked editorial comment in scientific journals, political magazines and in hearings on disarmament and arms control in the United States Senate.

Other investigations concerned the seismological implications of the large-yield underground nuclear explosion of November 1971 in the Aleutian Islands; geothermal phenomena in various parts of Canada, especially the Arctic; permafrost behavior; and a co-operative program between Calgary and Herstmonceux, England, on so-called plate-tectonic motions, i.e., the extremely slow lateral shifting of large blocks of the earth's crust.

Safety and Pollution Abatement in Mining and Metallurgy

The Mines Branch, apart from helping Canadian industry to rationalize its plants and to improve its output in fuels and metals, is also taking a leading role in showing Canadian mining and metallurgical companies

ways and means of increasing the safety of their staff and reducing the pollution of air and water resulting from their production processes.

In Canada, as in most industrialized nations, the highly concentrated and mechanized extraction methods used in modern mining have increased the amount of respirable dust. Studies are therefore being conducted in the department into the physics of airborne dust in its measurement, including the classification of mine environments in terms of dust hazards and mine ventilation.

A comparison of dust-sampling instruments in Ontario mines was completed in 1971, as a co-operative venture among the department, the McIntyre Research Foundation and the Mines Accident Prevention Association. The samplers are worn by miners going about their daily work. Field work was completed in 1971 on an underground trial to clean up mine air by filtration. Various substances were tested for cost and efficiency as filters, and vermiculite was found to be a practical filtration medium because of its low cost, even though its efficiency is only moderate. A drastic decrease in lung diseases among miners is looked for from this research.

Spontaneous combustion has troubled coal mines for many years, particularly in mining the softer coals. Heating in waste areas and seam fires has occurred in western coal mines. Fires in coal mines are a great danger because of the potential ignition sources of methane and dust explosions, along with smoke, carbon monoxide, and roof falls. The department is endeavoring to develop an underground detector of early stages of spontaneous combustion and a continuous monitoring system linked to a computer that will alert mine management.

In pyrometallurgy—the extraction of metal by heat—considerable progress was made in suppressing fumes produced by electric ferro-alloy furnaces. This metallurgical method is widely used in Canada and has given Canadian producers a competitive advantage. However, it is important to overcome the rather serious pollution caused by these processes. A novel method of controlling the silica dust from the silicon furnaces was devised and tested at a small scale with such success that patent applications were prepared. Research on a larger scale is continuing.

In the processing of Alberta tar sands significant amounts of fly-ash are produced. The ash causes pollution but contains valuable carbon, nickel and vanadium. A process that would permit extraction of these materials and at the same time solve the pollution problem is a highly desirable research goal.

A pilot-plant experiment confirmed that the carbon can be separated from the fly-ash by flotation, with acceptably low losses of nickel and vanadium. The carbon fraction was, in fact, sufficiently pure to be of economic value. The residue contained most of the nickel and vanadium, but was highly siliceous.

Three approaches were tried for reducing the silicon content of the material—a magnetizing roast, a metallizing roast, and flotation. None yielded encouraging results. Two new approaches are now being investigated.

The first consists in flotation of the coke feed before it is exposed to the high flame temperature of the boilers, in an attempt to separate the various constituents.

The second approach consists in completely reducing the nickel, iron, vanadium and a little silicon from the ash material, leaving most of the silicon in a slag, which can be discarded. This procedure concentrates all the metallic constituents in a fraction which has approximately one tenth of the original ash weight. Preliminary experiments indicate that good recoveries are possible, and that the nickel and vanadium can be separated by a partial oxidation of the metal.

The resurgence of underground coal mining in western Canada is threatened by two dangers—gas outbursts, which at present limit mining depth to 1,000 feet; and roof instability, which limits extraction and productivity. To take full advantage of the expanded market for coal, western coal mines will have to be aided in the development of new mining methods along with safety measures. The department is investigating the structural conditions of several coal fields in conjunction with roof-control and gas-outburst studies. Detailed mapping and analysis of existing roof falls and drill cores will be carried out at one property in an attempt to predict zones of potential roof fall. On-the-spot measuring techniques are needed to understand the mechanisms of gas outbursts and to develop control measures. Preliminary studies are now being carried out.

Another danger faced by miners is created by unsafe diesel engines. To eliminate this danger, the staff of the

Canadian Explosive Atmospheres Laboratory has been working on the design and instrumentation of a testing facility for diesel engines. The laboratory certifies diesel engines with respect to the emission of toxic gas and safety from the ignition of explosions. The use of diesel-powered equipment in new highly mechanized coal mines is expanding, and the testing facility will be greatly appreciated when it comes into operation at the end of the year.

A different problem is being faced at Springhill, Nova Scotia, where a bank of coal waste is burning and causing air pollution. Departmental researchers, assisted by the Department of Mines of Nova Scotia, have analyzed the situation and concluded that the hill contains 1.7 million tons of waste; some of this is burned out, but other areas contain sufficient combustible material to sustain the fire, and the pollution, for years to come.

The fire could be put out and the land reclaimed by moving, cooling, compacting and sealing the waste. It may be possible to reduce the costs of such an operation by using the coal in the waste for the generation of electric power.

Abatement of Air and Water Pollution

Air pollution from the combustion of fossil fuels continues to plague Canada's urban and industrial centres. Research into ways and means of producing cleaner flames and cleaner smoke therefore receives much attention from departmental experts.

To study burner aerodynamics a research tunnel furnace was built and put into operation. This furnace permits detailed studies of the heat-release from flames, and a longitudinal slot permits the flames to be probed for aerodynamic measurements, chemical composition and particulate production. This research facility enabled a study to be made of a series of twelve burners on behalf of the Oil Heating Association of Canada for the improvement of domestic oil burners.

Two plume surveys, one at Great Canadian Oil Sands Limited, Fort McMurray, Alberta, and one at Boundary Dam Power Station, Estevan, Saskatchewan, were carried out. Data from these two studies are being reduced and collated. These surveys were conducted to obtain a clearer concept of the influence of the local factors of climate and topography on plume dispersion. This information is essential to define the limits which must be placed upon energy generation in a given area with existing technology.

The improvement of oil-spill detection requires the development of analytical methods that are capable of characterizing petroleum accurately even after it has been subjected to considerable weathering that tends to preferentially destroy the saturated compounds. During the year good progress was made in developing a "fingerprinting" method based upon a chromatographic separation according to boiling point. This system involves two detectors, one for the sulphur-containing compounds, and the other for the hydrocarbons. Highly characteristic "fingerprints" obtained on Canadian crude oils give a very promising indication that this approach will be successful.

The major effort in elimination of pollutants from fuels has been made in the development of hydrogenation processes for the removal of sulphur from heavy low-grade crude oils, such as that which occurs in the Athabasca tar sands, and residual oils since this class of fuel must eventually be used to sustain a considerable proportion of the economy. Good progress was made during the year in defining the conditions for more economical refining of Athabasca bitumen by hydrocracking.

In areas where sulphide-bearing ores are mined and processed, acidic waters are generated through the oxidation of metal sulphides and become a hazard to the environment. The oxidation is often catalyzed by the action of bacteria on the ore sulphides. A simple pollution-control measure is the neutralization of such acidic waters with lime; the application of such neutralization techniques, which also precipitate much of the dissolved salts, was studied for several mining situations. Where properly done, this technique is very effective, but where further purification of the waste water is required, ion exchange appeared to offer the most feasible route, technically and economically, and studies were carried out to evaluate the principal factors governing the application of this technology.

Studies on improving the technologies for removal of dilute sulphur dioxide from stack gases were continued, in particular those techniques using lime or magnesia.

A detailed investigation has been undertaken of atmospheric pollution caused by gaseous and particulate emissions from the stacks of small cold-blast cupolas such as are used throughout the country by the small

iron foundries. The initial stages of this investigation consisted of the collection of samples and the concurrent monitoring of cupola-operating practice at six small foundries. Reductions in dust production of over half the range could be achieved by changes in operating practice.

An important new line of research initiated by the department concerns the use of waste material produced in mining and metallurgy. If waste could be turned into useful by-products, another polluting factor would be eliminated or at least reduced.

Long-term studies were completed on the conversion of waste gypsum from Canadian fertilizer plants into useful gypsum products. Results showed that gypsum products having properties such as time-of-set, strength, and bond to gypsum wallboard paper as good as those from natural gypsum plasters, could be produced by using by-product phospho-gypsum. Bases added to neutralize the acid by-product plaster of paris tended to lower the strength of the plaster but it nevertheless met CSA specifications.

Preparation of an inventory of Canada's waste-mineral resources was started. The inventory will be used as a basis for the selection of research projects on mineral-waste utilization. In addition, a mineral-waste index of past work and references has been established.

During the fiscal year 1971–72 efforts in the Mineral Sciences Division on those projects concerned with environmental improvement have significantly increased by comparison with the previous year. Studies of the processes occurring during the weathering of tailings and slag piles are being conducted under carefully controlled conditions; the biological, physical, and chemical aspects of weathering in tailings ponds and piles are being investigated.

Other environmental projects seek to modify treatment processes of sulphide ores in such a way that they will not result in the emission of sulphur dioxide, a noxious gas.

ICE STUDIES

The behavior of ice masses in the Arctic affects not only the security and navigability of shipping lanes, but also the climate and the terrain. Ice studies are generally conducted under the auspices of the Polar Continental Shelf Project.

For the tenth successive year, a systematic aerial survey was carried out of the distribution, nature and movement of sea ice in the main channels of the Arctic Archipelago.

Studies of the mass balance and physical behavior of Arctic icecaps continue. The crystallography and internal structure of the Devon Island icecap are being studied to determine its history and the climate of the region during the recent geological past. A core containing a complete sample of precipitation, particulate fallout and other impurities over the past 2,000 years has been obtained.

Scientists from McGill University under contract continue to study the Meighen Island icecap, particularly its influence on and reaction to the local climate. Emphasis has been placed on the energy exchange between the atmosphere and the earth's surface of known uniform physical properties.

In the arctic islands, Polar Continental Shelf Project personnel have conducted measurements of temperatures in and beneath the permafrost layer. The PCSP has fostered frozen-sea research into the seasonal variations in water structure in relation to the growth and decay of the sea ice. The PCSP has also given considerable support to various other government departments in such projects as live capturing and tagging of ringed seals, collecting and identifying insects, counting polar bears and following their movements, and other research peculiar to the high Arctic. This included various geological and geophysical projects as well as the evaluation of electronic position-finding systems.

The Arctic Ice Dynamics Joint Experiment (AIDJEX) is a co-operative effort on the part of Canada and the United States aimed at understanding the interaction between the fields of motion of the atmosphere, the pack ice, and the sea water. This understanding is basic to forecasting ice conditions and to assessing variations in surface/atmosphere circulation. The main AIDJEX activities are scheduled for 1974–75, but preparations are well under way, and a major pilot study to test instruments and techniques to be used in the project was done in the Beaufort Sea.

Resource Administration and Regulation

In Canada's constitutional framework the regulation and administration of natural resources in the provinces rest with the provincial governments concerned. The federal government retains jurisdiction over those resources in federal lands within provinces—such as national parks—or in federally administered territories, i.e., the Yukon and Northwest Territories and the continental shelves off Canada's coasts.

Within the federal government, there is a division of jurisdiction. The Department of Indian and Northern Affairs regulates natural resources in the two northern territories and in the Arctic continental shelf; the Department of Energy, Mines and Resources regulates resources in federal lands in the provinces and in the offshore areas of Hudson Bay and Hudson Strait and the east and west coasts of Canada. The regulatory power is exercised by the Resource Management and Conservation Branch.

The present intense exploration in the offshore areas is concerned almost wholly with the search for petroleum and natural gas.

The branch designs, issues and administers various types of terminable offshore mineral grants, taking into account the unique conditions of the offshore environment. These grants, varying from non-exclusive licences through exclusive exploration permits to production leases, are issued and administered under the Canada Oil and Gas Land Regulations. An extensive revision of these regulations was completed, the first in over ten years, and the revised regulations were expected to be promulgated in the last part of 1972.

The branch issued 387 Canada Oil and Gas Permits covering 31.1 million acres during the fiscal year. The number of offshore permits administered as of March 31, 1972, was 5,648 covering 402.5 million acres as follows:

East Coast — 4,259 permits — 315,583,260 acres

West Coast — 237 permits— 16,272,694 acres

Hudson Bay and Hudson Strait—1,152 permits—70,592,807 acres

The first application received during this period was for the conversion of two offshore exploratory permits to ten oil and gas leases, covering 131,223 acres in the Gulf of St. Lawrence. Revenues from offshore permits amounted to $508,830, made up mostly of permit fees and work-deposit forfeitures.

Although prospects for mineral resources other than oil and gas are promising in the offshore, exploration for these resources is on a relatively small scale. This is no doubt due to the much greater difficulty of locating and extracting such ores and minerals in the offshore environment.

Federal oil and gas leases in the provinces numbered 252 at the end of the fiscal year, distributed among Alberta, Saskatchewan, Manitoba and Ontario. Revenues from federal mineral leases in the provinces amounted to $397,540, most of which were derived from oil and gas royalties.

The discovery of oil, gas and condensate on Sable Island by Mobil Oil Canada presented new challenges to the engineering and geological staff, not only in the regulation and supervision of the increasing exploratory activity resulting from the discovery, but also in the detailed evaluation of the structural and reservoir conditions and hydrocarbon distribution within the Sable Island prospect itself.

The petroleum industry spent $55 million exploring for oil and gas on permits administered by the branch: $17 million for geophysical and geological surveys and $38 million for exploratory drilling. Cumulative industry expenditures in Canada's offshore to the end of 1971 reached $200 million, consisting of $100 million for geophysical and geological surveys and $100 million for drilling.

The department approved 140 separate offshore exploratory programs during 1971 (including 21 exploratory drilling projects in the east coast offshore), all of which were monitored to ensure adherence to federal requirements designed to minimize the possibility of accidents causing pollution or the waste of resources, and to protect human safety and the living resources of the sea.

Senior officials of the department continued to represent Canada at meetings in Geneva and New York of the 91-member United Nations Committee on the Peaceful Uses of the Seabed and Ocean Floor beyond the Limits of National Jurisdiction. At issue here, among other matters, is the definition of the outer limit of national jurisdiction and the nature of the international regime and machinery required to manage the seabed resources of the area beyond. Much is at stake for Canada, and departmental officers are playing a very active role in the discussions and working groups of the committee.

The department also participated in negotiations with the United States, France and Denmark with respect to the delimitation of offshore boundaries of jurisdiction over seabed resources in the Gulf of Maine, St. Pierre Bank and Baffin Bay regions.

Services and Statutory Responsibilities

Legal Surveys in Federal Lands

Although provincial governments have jurisdiction over legal or land surveys in their territories, the federal government, through EMR's Legal Surveys Division, carries out and supervises such surveys in federal lands within provinces (i.e., national parks and Indian reserves) and in the northern territories. The division also undertakes certain other tasks, such as the demarcation of interprovincial boundaries and the certification of Dominion Land Surveyors.

During the year 22 field parties completed 146 separate survey projects: 76 on Indian reserves in all provinces except Newfoundland, Prince Edward Island and Nova Scotia, 3 projects in national parks, and 67 in the Yukon and Northwest Territories. To complete as many as possible of the projects required for federal government departments, 73 were done under contract.

Assistance was rendered to the Department of National Resources of New Brunswick in connection with its Atlantic Provinces Survey and Mapping Program preparatory to setting up an integrated survey area for Saint John and Kings Counties.

A major undertaking was the planning and preparation for the decentralization of the Field Survey Section, with nine regional offices to be established across Canada.

Technical instructions were issued for some 343 surveys in Crown Canada Lands.

Two federally appointed commissions, chaired by D. R. Slessor, the new Surveyor General of Canada Lands, worked on the survey and maintenance of provincial boundaries. The Manitoba-Saskatchewan Boundary Commission surveyed the remaining 30 miles of boundary, thus completing the actual field work. On the British Columbia-Yukon Territory boundary, 160 miles were resprayed with a defoliant, since the 1969 spraying of this area proved to be unsatisfactory.

The Board of Examiners for Dominion Land Surveyors met nine times. Of the 28 candidates who sat the 1972 annual examination at Ottawa, Edmonton, Calgary, Vancouver and St. John's, two passed the preliminaries, one the intermediate and eight the finals, the last qualifying for the Dominion Land Surveyor commission.

Aeronautical Charting

The federal government exercises exclusive jurisdiction and provides exclusive services in the field of aeronautical charting and the publication of pilot's handbooks. These show locations and approaches to airports along with the electronic aids to air navigation.

During the year, 52 different map series and flight-information publications were provided, and conversion of the World Aeronautical Charts at a scale of 1:1,000,000 to a new format was well in hand.

The division began a review of all charts for the so-called visual flight rules (VFR). Charts for southern

Canada will be reviewed every two years and those for northern Canada every four to five years.

New schedules for amendments to the *Canada Air Pilot* and the *General Pilot Handbook* were instituted, and the experimental operation of a new electronic air-traffic control at Moncton necessitated the production of special aeronautical charts, up-dated every four weeks.

A number of charts have been developed in conjunction with the evaluation of a Short Take-Off and Landing (STOL) service between Ottawa and Montreal. A *Toronto Terminal Radar Service Area Map* was produced to assist visual-flight-rule pilots through the controlled area. The preparation of a new publication covering the Northwest and Yukon Territories is under way.

International Boundary Commission

In 1925, Canada and the United States signed a treaty establishing a permanent International Boundary Commission, which was to maintain the international boundary properly marked out and cleared of tree growth. It was also to resurvey parts of the boundary, when and if this should become necessary.

The Canadian section of the commission is, for operational purposes, incorporated in the department's Surveys and Mapping Branch.

Canadian field parties operated in three areas during the year. On the Manitoba-Minnesota section, the boundary vista was recleared for 10 miles at the eastern end of the 49th parallel. Some 75 miles of the New Brunswick-Maine section was controlled by a chemical treatment and 20 miles of vista was recleared; 276 monuments were inspected and one was repaired.

On the Quebec-New Hampshire boundary 55 monuments were inspected along Halls Stream. Two reference monuments were relocated and three were repaired. On the Quebec-Vermont boundary a geodimeter traverse was run along the boundary and ties were made to the associated control triangulation; 96 monuments were inspected, 8 were repaired and two new marks set.

During the year, the Commission developed a lightweight inner tower to support the instrument when surveyors are making precise angular measurements from survey towers. A patent application has been filed on behalf of the Canadian Government.

Explosives Administration

The Explosives Division, a unit of the Mineral Development Sector, is responsible for regulating all factories that produce commercial blasting explosives, military explosives, blasting accessories, gunpowder, smokeless powders and percussion primers, ammunition, fireworks and other pyrotechnics, and for the quality and safety of their products. This responsibility extends also to the road transportation of these items and to their storage and importation.

Control is exercised by a system of licences, permits and sales records supported by inspections by members of the division and by the Royal Canadian Mounted Police. All licences and permits are issued from the Ottawa office.

A general quickening in construction and mining activity was reflected in an increased office and inspection workload with which the division was just able to cope. The number of factory licences continued to increase as expected, reaching a total of 55 by year end, mainly due to the expansion of on-site slurry or water-gel manufacturing facilities at additional open-pit mines. Two factories manufacturing sporting ammunition ceased operations. The number of licences issued for the storage of blasting explosives in support of construction projects, road building, seismic exploration, pipeline laying, erection of transmission towers, forestry and like operations increased to over 1,200.

A new hobby for youth—model rocketry—has been rapidly gaining popularity. By year end, 39 licences had been issued to hobby shops across Canada to permit the sale of model rocket engines to individuals licensed as firing supervisors by the Canadian Association of Rocketry, a division of the Youth Science Foundation of Canada. The small rocket engines used in this sport consist of a propellant explosive, and although relatively innocuous in themselves, even if involved in a fire, can accelerate to the speed of a bullet shortly after launch and can push a rocket to heights in excess of 2,000 feet. These properties make them a hazard to aircraft or to the public, if misused.

In the past few years, the increased use of explosives for criminal activities throughout Canada has created

a situation whereby the orderly marketing of explosives for legitimate and necessary purposes is being seriously hampered. The division mounted a two-pronged attack on this problem. First, amendments to the Explosives Act to provide for greater control over the purchase, possession and transportation of explosives were proposed. Bill C7, an Act to amend the Explosives Act, was introduced in the House of Commons on February 21, 1972. Secondly, in co-operation with explosives manufacturers and distributors, provincial mines departments and other departments and public agencies, and with the assistance of the Royal Canadian Mounted Police, new construction standards for blasting-explosives magazines were developed. These standards, which have been well received by vendors and users, require that magazines be bullet-resistant, fire-resistant, theft-resistant, weatherproof and well ventilated. A booklet entitled *Standards for Blasting-Explosives Magazines* was published and distribution started. Conversion of existing magazines or construction of new ones to these standards is under way, with a target date of December 1973 set for completion of the project.

Members of the Explosives Division promote safety programs and regularly meet with members of industry, federal and provincial government agencies, municipal authorities and other groups involved with the handling of explosives. The division also has available for distribution safety literature on the storage, handling and transportation of explosives.

Research Agreements

The several programs of grants in aid of research previously managed by different branches of the department were combined during 1971 into a common departmental program under the name "Research Agreements." Eligibility for participation in the new program was extended to Canadian research organizations other than universities. Whereas under the old system the support of university research was the chief criterion, under the new system relevance and contribution to the department's objectives were adopted as the chief criteria. All disciplines involved in the discharge of EMR's responsibilities were included. The intention was to bring many kinds of expertise to bear on the problems of national policy, to apply a multidisciplinary competence to the development of advice to government and information for the community at large.

The branches of EMR, with their disciplinary orientation, were responsible for assessing the proposals which related to their own activities and, in general, for maintaining contact with the investigators on substantive matters throughout the life of the agreement. Administrative matters were centralized in the Departmental Grants Committee with J. M. Harrison as chairman and T. E. Bolton as secretary.

No significant increase in the level of funding ($576,000) over previous grants in aid of research was provided for the EMR Research Agreements to be spent in 1972–73. The committee received 331 applications, requesting a total of $3,830,604; of these 92 Research Agreements were recommended by the branches—86 to university projects, 5 to provincial science councils, and 1 to the Royal Ontario Museum.

Administration and Support Services

Under this heading, the report describes the non-operating units of the department—those dealing with administration, finance, personnel, public information, etc.

Executive Offices

Top-management structure of the department was reorganized during the year. A Senior Assistant Deputy Minister and an Assistant Deputy Minister (Planning and Evaluation) were appointed, and authority was received for the establishment of an Assistant Deputy Minister (Administration).

The top executive officials of the department, with their respective responsibilities (where applicable), are indicated on the organization chart.

These officials, together with certain senior officers of the department, form a permanent Executive Committee, which helps to set departmental policies and priorities. A Management Committee, with wider membership, provides a link between the Executive Committee and the operating units. Plans were being made in 1971–72 for the establishment of a Departmental Secretariat, which would provide support services to the Executive and Management committees, provide liaison with Parliament, and fulfill certain other functions.

Personnel Services

On March 31, 1972, EMR had a full-time staff of 2,843, an increase of 141 from the preceding year. The department also employed approximately 2,100 casual employees, among them students and those on the winter-works program.

The Personnel Branch provided training within the department to approximately 15 per cent of the staff, chiefly in management.

The department's suggestion award plan achieved the highest overall standing in the Public Service of Canada, in terms of number and quality of suggestions per 100 employees.

Representatives of the Personnel Branch assisted in renegotiations of all but one of the 30 collective agreements covering EMR employees. Contingency plans were developed for breakdowns in labor relations, such as strikes. At year end, development of a formal framework for union-management consultations was well under way.

Although the number of classification requests increased slightly, personnel officers succeeded in reducing the average time needed to process submissions by more than 50 per cent over two years.

Finance and Administration

This branch includes Financial Services, Property Planning and Management, Administration Services (including Materiel Management and Technical Field Support Services) and Management Services. These units continued to provide the department with services in accounting, finance, program forecasts and estimates co-ordination, management of materiel, property plan-

ning and management, telecommunications, mail, central records, technical field support (materiel and equipment), and related areas.

During the last few years it had gradually become apparent that the staff of the department was outgrowing the Booth Street complex, and especially the modest administration building. A number of branches —such as Mineral Resources, Personnel, Public Relations and Information Services, the new Energy Sector —had to move wholly or partly to temporary quarters around Ottawa. To bring these units back together and to provide more suitable office space, a new office tower was planned for the Booth Street site and construction began during the year. The building is to have 21 floors and will cost approximately $10 million.

Outside of Ottawa, additions to existing buildings for the storage of drill cores were completed in Bedford and Calgary, and modifications were made to existing hangar space at Uplands Airport near Ottawa.

A major renovation was carried out in a building on Sheffield Road in Ottawa, for the Canada Centre for Remote Sensing and the Air Photo Production Unit.

Public Relations and Information Services

Services rendered include the publication of booklets, pamphlets, etc., and photos on the work of EMR, contact with Canadian and foreign news media, and editorial and publishing service to the scientific branches of the department.

Publicity arrangements were made for the 23rd Canadian Conference on Coal, the Chinese Mining Mission to Canada, the Remote Sensing Symposium in February 1972 and the Workshop on Gold-Mining Communities. The Canadian Institute of Mining and Metallurgy and the Canadian Institute of Surveying were assisted at their annual conventions in Ottawa and Quebec City, respectively.

Information programs were drawn up, with the cooperation of the participating departments and agencies, for ministerial news conferences on (1) expanded guidelines for the construction and operation of northern oil and gas pipelines and (2) Canada's remote-sensing program, which were held in June and July of 1972.

Advance publicity arrangements were made for three international scientific congresses to be held in Canada in July and August of 1972: the International Geological Congress, the International Photogrammetric Congress and the International Cartographic Congress.

Some 15,000 letters requesting information and publications were processed. A marked increase was noted in queries from the public and industry on oil and gas production, resource policies and mineral development. A number of inquiries concerned foreign ownership. Over 5,000 telephone inquiries were received from the press, public and industry.

Publications of a scientific or technical nature produced in 1971–72 include four issues of the *Canadian Metallurgical Quarterly*; Proceedings of the Sixth Rock Mechanics Symposium; Proceedings of the 22nd Canadian Conference on Coal; *Non-ferrous Metals Casting—History and Forecast*; numerous geological Bulletins, Memoirs and Papers, in English and French; and a wide range of earth-physics reports dealing with seismology, gravity and geomagnetism.

Computer Services

In October 1971 the Computer Science Centre installed a Control Data 6400 computer. This was done to satisfy the increasing computing workload of the Department of Energy, Mines and Resources and some sections of the Department of the Environment. At the same time the installation will effect cost reduction by centralization of computing on one large computer.

The CDC 6400 replaced a CDC 3100, which was transferred to the Canadian Centre for Inland Waters in Burlington, Ontario, and it is also processing most of the work previously contracted to computer utilities in the Ottawa area.

The new system provides seven terminal devices, located in the various departmental buildings in Ottawa, that are connected to the computer by telephone lines. Work may be submitted from any building, transmitted to the central computer, processed and the results transmitted back. This creates the effect of having a computer conveniently close to all users, and productivity is increased by eliminating the delays associated with the physical delivery of work to and from the computer.

Legal Services

The senior legal adviser and his staff of two solicitors are members of the Department of Justice assigned to EMR to render advice to its many components. The senior adviser is a member ex officio of the department's Executive Committee and for administrative purposes reports to the senior assistant deputy minister. The work of the office covers a wide range of activities, including the drafting of major contracts, advising on the legal implications of policy decisions, drafting of regulations and helping to draft new legislation.

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Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

annual report 1972-73

Hon. Donald S. Macdonald, Minister

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INTRODUCTION

The Department of Energy, Mines and Resources is the federal government's principal agency for policy development in the fields of energy and minerals, and the principal centre of related activities, including landmass surveys; the assessment of Canada's potential in a broad range of non-renewable resources -- fuels, metals, industrial minerals; the dissemination of many types of scientific and technical information; and the analysis of economic and industrial trends in the fields of energy and mineral resources.

The world oil crisis which was to develop as a result of the Middle East problem in late 1973 was recognized as a potential threat during the period covered by this report, and the energy specialists of the department were heavily involved in the collection and interpretation of energy data looking toward the elaboration of a new national energy policy. Evaluation of Canada's energy and resource potential also occupied much of the capacity of other branches, such as the Geological Survey, the Mineral Resources Branch, the Earth Physics Branch, the Mines Branch, etc., in addition to their continuing research and surveys.

Probably the most significant event in the field of science and technology was the launching of the Earth Resources Technology Satellite (ERTS) by the U.S. National Aeronautics and Space Administration in July 1972. Through an agreement with NASA, EMR's Canada Centre for Remote Sensing is able to receive and distribute imagery of Canadian territory transmitted by ERTS. The imagery, in four spectral bands, is transmitted to a receiving station at Prince Albert, Sask., and taped for further correction and processing in Ottawa. Photographs of the imagery are sold through the National Air Photo Library, a unit of the department's Surveys and Mapping Branch.

There is no transfer of funds involved in the NASA-EMR agreement, which has provided Canadian resource planners with a new, comprehensive, continuously updated overview of Canada's land and water areas. Many uses have already been made of ERTS imagery in various fields of research. One interesting experimental application was the transmission of ERTS imagery of the Arctic, via satellite, to ships travelling through the Arctic sea lanes, giving the ship captain almost instant overviews of ice conditions over hundreds of miles.

The airborne remote-sensing arm of the newly established Canada Centre for Remote Sensing has also been building up its capabilities and has flown a large number of missions requested by users in many parts of Canada. It can call upon the services of four specially equipped aircraft for low- and high-level sensing missions.

Coal is a fuel whose reserves appear much greater than those of oil and gas, but they are widely scattered and of varying degrees of quality and accessibility. The department is developing a methodology for evaluating coal resources in terms of recovery and economics. The methodology is designed to be adaptable to changes in mining and combustion technology.

As part of a joint federal-provincial program to obtain a more accurate assessment of lignite resources in Saskatchewan, a drilling project was launched, in which more than 200 holes were drilled, and more than 2,000 samples were analyzed. The work will continue in 1973.

The department has been giving special attention to the Task Force on Northern Oil Development, which is chaired by the deputy minister. Pipeline guidelines based on the recommendations of the Task Force were established in 1970, and draft environmental and social guidelines were published in June 1972. To provide information and advice concerning the financing of a northern pipeline, which would involve expenditures of at least $5 billion, the Minister of Energy, Mines and Resources established a National Advisory Committee on Northern Pipeline Financing. The committee is made up of senior representatives of the financial community in Canada.

The outlook for Canadian uranium mines brightened in 1972, with a sales agreement with several Spanish utilities for the delivery of approximately nine million pounds of uranium from 1974 through 1977, at a total value of

about $60 million. Some six million pounds will come from the joint stockpile maintained by the federal government and Denison Mines, which was started in 1971; the other three million pounds will come from the general government stockpile. Both stockpiles were designed largely to maintain the Elliot Lake mining community.

The need to use and exploit the environment often leads to conflict, and rational management requires a broad knowledge base to which the studies of modern geological processes contribute. The Geological Survey has carried out a wide variety of studies under this general objective. Some of them deal with provision of use-hazard information on the behavior of earth and rock materials under specific conditions, especially in the Arctic regions where the extreme sensitivity of the terrain to man-made disturbance has become a matter of public concern.

Another area that is receiving ever more geological study is Canada's continental shelf, east, west and north. The shelf off eastern Canada has been the object of surficial and bedrock geological mapping and systematic geophysical surveys. In the Arctic, a unique co-operative venture between six oil companies and three EMR branches resulted in a seismic profile across the Sverdrup Basin, in which the attitude, nature and thickness of the various sedimentary strata overlying the basin were mapped.

A major geological project in 1972 was a regional geochemical reconnaissance by lake-sediment sampling of 36,000 square miles north-east of Yellowknife. This study, when its results were made available to the public, induced the staking of 200 claims.

Although map-making in EMR's Surveys and Mapping Branch has kept pace with technological advances in that field and the output is now much higher than ever before, experimentation is continuing on speeding up mapping through greater automation. A so-called "Automated Cartography Project" entered its production-development phase in 1972. A block of map sheets at a scale of 1:50,000 in the Yukon Territory was assigned for production by automated methods.

The economists of the Mineral Resources Branch continued to carry out research and to formulate recommendations concerning the degree of domestic processing and the use of minerals in relation to economic diversification or conservation of resources as appropriate to minerals.

The Mines Branch carried out further experiments in the hydrocracking of Alberta bitumen to study the effect of four operating variables on product yields, pitch conversion, and sulphur removal; the results helped to clarify problems associated with mechanical design and operating conditions that would improve liquid yields. Hydrogenation can convert up to 85 per cent of the bitumen to liquid fuel that is suitable for the manufacture of low-pour-point oils for arctic and aircraft use.

Other work done at the pilot-plant scale sought to achieve economical desulphurization of coal from the Lingan area in Nova Scotia, in order to produce metallurgical coal of coking grade for local steelmakers and possibly for export. A modular-type pilot plant was assembled and brought into operation using the EMR process based on compound water cyclones, and considerable progress was achieved.

The construction of northern pipelines raises problems such as the behavior of metals and alloys at very low temperatures. A comprehensive program continued on the evaluation and improvement of pipe steel that would provide structural rigidity of oil and gas pipelines and consequently ensure environmental protection.

Further improvements were made by the scientists of the Earth Physics Branch in the equipment for detecting and measuring natural and man-made earthquakes, such as nuclear explosions. Preliminary tests on tape-recorded data indicate that the automatic on-line digital processing system scheduled to begin operation at the Yellowknife seismic array in 1973-74 will achieve a very good detection level, thus contributing substantially to the world-wide monitoring of seismic events. The Canadian scientific effort in this field continues to play a leading role in dealing with problems in policing a ban on nuclear testing.

One of the most ambitious research projects ever launched in the Arctic is AIDJEX -- short for Arctic Ice Dynamics Joint Experiment -- carried out in co-operation between Canadian and United States agencies. The project is aimed at studying the dynamic behavior of sea ice, and the transfer of kinetic and thermal energy between the atmosphere and ocean through a complete or partial ice cover. Scientists hope that the information thus obtained will enable them to calculate and predict the movement of sea ice, climatic trends, and engineering factors needed for the design of fixed or

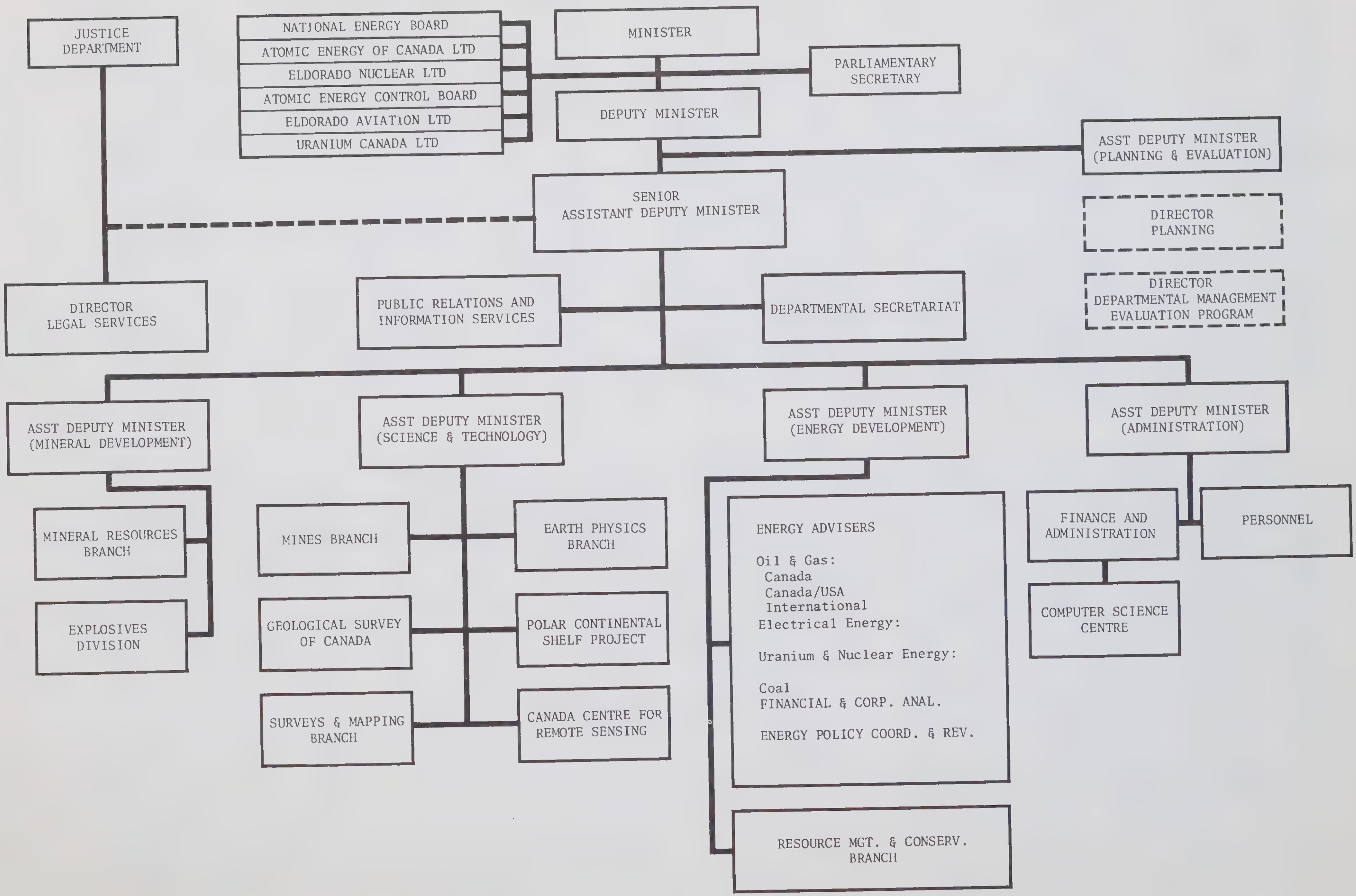
moving structures associated with resource development in or near the Arctic Ocean.

In 1972 Canada was host to the XXIV International Geological Congress, with an attendance of more than 5,000 at the meetings in Montreal. As the principal geoscience agency of the federal government, the department played a significant role in all aspects of the Congress and staff members, particularly of the Geological Survey, were active participants as authors of papers presented at the formal sessions, as members of organizing committees and as leaders of the field excursions which took geologists from many countries of the world to all parts of Canada, from east to west and to the high Arctic.

Canada also acted as host for the Fourth General Assembly and Sixth International Conference of the International Cartographic Association, and for the International Society of Photogrammetry Congress.

These are some of the highlights of the work of EMR during the fiscal year 1972-73. Other activities, in greater detail, are described in the pages that follow.

DEPARTMENT OF ENERGY, MINES AND RESOURCES



RESOURCE INVENTORY AND POTENTIAL

MAPPING

Control surveys. The Department of Energy, Mines and Resources is responsible for the establishment of national frameworks to serve the needs of mapping, charting, cadastral and boundary surveys, national security, geoscience research and related activities.

Field surveys were carried out in many parts of Canada, adding to and improving the national frameworks. With the help of the Department of Public Works, a first-order level line was started along the Mackenzie River from Fort Providence, NWT. This line will provide accurate vertical control for development projects along the Mackenzie River and the Mackenzie Corridor, and will be the first high-order level line to reach the Arctic Ocean.

An assessment was started of the accuracy of all geodetic horizontal control in Canada.

The Geodetic Data Centre averaged 15 visits or telephone requests for data per day, in addition to 1,200 written requests during the year.

Maps. The Department of Energy, Mines and Resources is the principal mapping agency in Canada. In fulfilling its role of taking the measure of Canada's land areas and publishing the results in the form of maps and statistical tables, it produces maps and charts of many types and for many different purposes. The task of mapping a nation so vast must be a continuing enterprise, for as long as economic expansion persists and new sources of wealth are discovered, it will be necessary to add to information in cartographic form. Such information must be available for the enlightenment, use and reference of all Canadians.

In 1972-73, 352 National Topographic Series maps were compiled to the scribing stage, comprising 49 new maps to be produced in full color, 92 monochrome maps and 211 revision maps. In addition, 78 photomaps were forwarded for production.

There were 310 additional monochrome maps sent to contractors for the placing of "surround" information. These will be forwarded for production within the first three months of the fiscal year 1973-74.

Compilation of new and revised maps was reduced somewhat this year in order to prepare and assemble information for the Mapping Data Base of northern Canada. This Data Base project stems from the fact that the field surveying and aerial photography of Canada has reached the state where it is now possible to carry out, for vast areas of northern Canada, the initial stages of mapping (i.e., the measuring of the corner points of the aerial photos and the adjustment of these points to the ground survey grid). The actual drawing of 1:50,000 maps would not be done until a requirement for such mapping was established, but with the initial measuring completed (and stored in the Mapping Data Base) the maps could be drawn and printed very quickly. This concentration, during 1972-73, on the initial stages of a very large number of maps has had the effect of reducing the completion of maps below the normal annual production of the Topographical Survey Directorate. It is expected that this drop in production will last only one year.

Field work was completed on 262 maps by 24 parties operating in seven provinces and one territory.

The Topographic Mapping Division planned and inspected 1:50,000 and large-scale mapping contracts for various federal agencies amounting to approximately $1,000,000 undertaken by private aerial-survey companies. One of the major projects was the aerial triangulation, numerical adjustment and 1:50,000-scale mapping of various parts of the Mackenzie River Corridor.

The department's draftsmen completed 303 new and

revised multicolor topographic maps and 164 monochrome prints. They also revised 15 index maps of the National Topographic Series. Printed during the year were 242 new and 190 revised multicolor topographic maps, 221 monochrome prints and 200 airphoto maps.

As during the previous winter, a cartographic unit was established in Vancouver, B.C., under the terms of the Federal Direct Employment Plan. The project ran from January to May 1973 and employed 45 draftsmen for most of the period.

The Surveys and Mapping Branch also prepared a large variety of special maps to accompany various publications and reports published by government agencies. Other maps dealt with such subjects as high-voltage lines and generating plants, radio and television coverage of Canada, areas served by Manpower centres, areas covered by permits for oil exploration, arctic shipping safety zones, coverage of Canada by the Earth Resources Technology Satellite, the Canadian highway network (for the Canadian Government Travel Bureau), etc.

Printing of maps surpassed previous records with an output of 42 million impressions, resulting in more than nine million copies of 2,850 maps and charts.

By the end of fiscal year 1972-73 the English and French editions of the National Atlas of Canada were within three months of their scheduled completion date. The first printing of the new Atlas will be distributed in loose sheets. Plans are being made for the second printing to be issued as a bound volume. As the Atlas entered its final phases, work was started on the next edition.

Approximately 3.5 million maps and charts were distributed. Certain changes in map and chart formats resulted in the reduction of paper quantities required in printing.

The most important outlet of the Canada Map Office is the network of 374 map dealers and 315 aeronautical-chart dealers. There are also 138 map depositories, where the public may obtain information on topographic map sheets.

Air photography. The National Air Photo Library, which has a stock of 3,726,000 contact prints in its reference file, received 13,353 requests for the reproduction of photography or information concerning available coverage. This compares with 9,569 requests received in 1971-72. Requisitions for photographic reproductions numbered 10,155.

The work of the National Air Photo Library (NAPL) grew in volume and complexity with the increase in remote-sensing imagery -- airborne and satellite -- ordered and distributed from its offices. Close links have been set up with the Canada Centre for Remote Sensing.

The move of the reproduction centre of the National Air Photo Library from the Canadian Forces Base Ottawa (North) to more suitable quarters at 2464 Sheffield Road (shared with the Canada Centre for Remote Sensing) took place in April 1972. With the acquisition of a substantial amount of new equipment during the year, the centre is regarded as one of the most modern photographic facilities in the world.

The Earth Resources Technology Satellite (ERTS), which provides remote-sensing imagery of all Canada from an elevation of about 500 miles, was placed into orbit in July 1972; the reproduction of ERTS imagery was assigned to the centre. With this new duty, the annual production of ERTS, airborne sensing and air-survey photos came to over one million products.

The department is host to the Interdepartmental Committee on Air Surveys, which is responsible for contracting aerial photography flown for and on behalf of the federal government. Thirty such contracts were let, amounting to $907,071. A total of 74,600 line-miles of photography was obtained in 1972, divided almost equally between propeller and jet aircraft. The Mackenzie Highway project accounted for all the non-jet air photography. Because of what appears to have been a malfunction in the cameras, a considerable part of the jet photography turned out to be unsuitable for mapping purposes.

The trend toward air photography for purposes other than mapping continued. Such photography is often ordered for assessing changes in biological and/or agricultural conditions.

Geographical names. The secretariat of the Canadian Permanent Committee on Geographical Names supervised the publication of the New Brunswick Gazetteer (second edition) in the Gazetteer of Canada series. It contains more than twice as many names as the first edition. Work continued on other gazetteers.

In May 1972, the chairman of the committee, J.-P. Drolet, and the executive secretary, G.F. Delaney, participated in the Second United Nations Conference on the Standardization of Geographical Names in London, England.

The history of geographical names in Canada and related subjects was researched. The staff continued to process a wide variety of toponymic submissions from government and private sources.

Geological mapping. Inventory mapping provides the data needed to establish the systematic geological framework that is the basis for estimating the potential for minerals and fuels in Canada. This framework is portrayed mainly by various maps that show three-dimensional data combined with the fourth dimension — time — and is identified by the National Bedrock Geological Reconnaissance (scale 1:500,000 or smaller) supplemented by upgrading surveys in areas where older reconnaissance work is not sufficiently detailed for today's needs.

Reconnaissance mapping for Operation Snag-Yukon was completed and preliminary results were published. Similarly, the final field phase of Operation Stewart (Yukon and western District of Mackenzie) was completed. Detailed stratigraphic studies were conducted to supplement the available data. The area is of economic interest as it contains tungsten, lead-zinc, and a coal deposit, the last having been discovered by members of the mapping team.

Inventory mapping of Yellowknife and Hearne Lake map-areas (1:250,000) was completed, and upgrading of additional map-areas to the northeast in this economically important area is expected to continue. Similar upgrading was started in several map-areas in the District of Keewatin originally mapped on a reconnaissance scale some 20 years ago during one of the first helicopter operations. Indications of sulphide mineralization were encountered but require further evaluation. Similar mapping was done in the Berens River area of Manitoba.

In addition to inventory mapping in bedrock areas, the mapping of surficial deposits was continued; indeed, in terms of personnel employed, this aspect probably was the more extensive. Such activities extended from terrain mapping in south-central British Columbia in co-operation with the provincial government, or mapping in the Winnipeg area, to studies of surficial geology and geomorphology in the Arctic Islands.

Until recently there has been little demand for terrain information from mountainous areas, but with the increasing pressure for information on all facets of the land it has become necessary to develop a scheme for classifying and mapping such deposits. A pilot study was carried out last summer in the Revelstoke area.

Many geological mapping activities depend on information supplied by a wide range of specialists who, because of their training, are able to make use of what appears to the unspecialized worker to be of slight importance. During the report period, more than 2,000 lots of fossils were examined by paleontologists of the Geological Survey. In addition, paleontological studies were done in the field, such as the biostratigraphic studies in Newfoundland, studies of conodonts from arctic Canada or biostratigraphic work on northern Vancouver Island.

A knowledge of the magnetic properties of rocks and minerals can assist greatly in solving problems that arise in inventory mapping; during the report period, an extensive study of the paleomagnetism of the Lac Saint Jean, Sept Iles and Allard Lake anorthosites was started.

Laboratory specialists did more than 2,200 analyses in support of geochronological (age) studies of rocks and also did radio-carbon analyses of material less than 30,000 years old to assist in determining the age of their enclosing strata.

The geological framework of the eastern continental shelf and margin of Canada is known only in general outline. During the report period this area was the object of surficial and bedrock geological mapping and systematic geophysical surveys. Five regions were studied: a) Nova Scotia Shelf, Bay of Fundy and Southern Grand Bank; b) Gulf of St. Lawrence; c) Northeast Newfoundland, Labrador Shelf and Sea; d) Baffin Bay and adjoining Sounds and e) Nova Scotia Grand Banks Continental Margin and the adjoining deep ocean floor. Similar submarine geological and geophysical surveys were made along traverses normal to the coast on the Pacific Continental Shelf for basin analyses, fuel and mineral potential, delineation of the continental margin for the purposes of establishing Canadian sovereignty, and engineering and environmental considerations for seabed development on the shelf and slope.

In support of geological mapping and other aspects of the scientific program, the Geological Survey published 48 new geological maps, 44 preliminary reports and 15 final reports; some of these reports were of considerable size, comprising hundreds of pages of printed text and many illustrations. In addition, continued public interest necessitated reprinting 21 reports and 12 geological maps. Open-file releases continued to provide an expeditious means of releasing interim results of Survey investigations to the public. Fifty-six open files were prepared, some of them consisting of many maps and sheets of data of immediate interest to those concerned with Canada's resource inventory and potential.

Geophysical mapping. Along with topographic,

special-purpose and geological maps, Earth Physics Branch scientists also produce data for maps showing magnetic, gravity and seismic patterns in and around Canada. Such maps are used in navigation -- sea and air -- and in exploration for minerals and petroleum.

In late 1972, a three-component airborne magnetic survey covered the Yukon Territory, the District of Mackenzie, Alberta, Saskatchewan and the western part of Manitoba. The distance flown was 60,000 nautical miles; survey lines were 20 miles apart, and altitude ranged from 8,000 to 16,000 feet.

Field parties made observations at 22 repeat stations in eastern Canada, as part of the annual updating of the ever-changing magnetic map of Canada.

The earth's magnetic field is seldom quiet. It responds to activity in the sun. Large disturbances, known as magnetic storms, are usually associated with sunspots and other visible eruptions on the solar surface. The changes in the strength and direction of the magnetic field are recorded continuously at 10 magnetic observatories extending from St. John's to Victoria and into the Arctic. One of the most intense magnetic storms ever recorded began on August 4, 1972, and lasted several days. It disrupted not only communication circuits, but even electric-power-distributions systems, tripping circuit breakers repeatedly and burning out transformers.

Natural magnetic disturbances also have useful applications. They induce in the earth electric currents, which depend on properties of the rocks underground, their composition, temperature and structure. By recording these electric currents and the magnetic fields produced by them, scientists can study the earth's crust to depths of 50 miles or more, well beyond the range of classical geological methods.

During the spring of 1972, unmanned magnetic recording stations were operated on the ice of the Arctic Ocean north of Ellesmere Island. Analysis of the magnetic variations recorded indicates that the great anomaly of electric conductivity which sweeps under Ellesmere Island for 500 miles extends northward beneath the Arctic continental shelf for at least 120 miles. This discovery may have important consequences in the understanding of the geological history of the Arctic Islands.

A long-term investigation by paleomagnetic methods of the history of the Canadian Shield continued with field collections from Superior, Grenville and Archean terrains, in collaboration with the Geological Survey of Canada, and Toronto and Carleton universities. A consistent picture extending back to 2.5 billion years ago is now emerging.

In the field of gravity mapping, surveys to extend the national gravity survey of Canada continued during the year in the Arctic, British Columbia, Quebec and the eastern offshore. In co-operation with the Polar Continental Shelf Project, field work was carried out on the sea ice in Mackenzie Bay and adjacent areas of the Beaufort Sea. As a result of this work, a new gravity map will be published in 1973, which will be of interest to companies carrying out oil exploration.

In Quebec an intensive survey in a 24,000-square-mile area in the Labrador trough was carried out with the co-operation of the Geological Survey and the Surveys and Mapping Branch. This survey was the first in a series to study in detail various regions of Canada that appear to offer good opportunities for crustal studies by gravity methods, for the ultimate benefit of mining.

Responding to growing interest in the Atlantic offshore, a geophysical investigation of the Nova Scotia continental shelf was started, combining gravity, magnetic and seismic methods. These studies will be extended to other suitable areas of Canada.

Gravity experts continued their study of lunar rock samples, particularly the effect of high-velocity meteorite impact. Space exploration was also in the focus when Apollo 17 astronauts were briefed on aspects of cratering at Sudbury as a preparation for their study of lunar craters.

The Seismology Division, using recently developed interpretation techniques, undertook a review of all previous work in the Rocky Mountains area which, combined with seismic methods, will result in a unified interpretation of this important region. Seismologists completed the interpretation of the crustal and upper-mantle structure from a refraction experiment carried out in the Shield areas of Quebec. They also made long-range refraction observations in the Sverdrup Basin in the Arctic, an experiment carried out jointly with the Geological Survey.

<u>Mapping under the auspices of the Polar Continental Shelf Project</u>. This project, which provides logistic and other support to a large variety of scientific research and technical surveys in the northern Arctic, again made a major contribution to greater knowledge of Canada's northernmost territories.

Quaternary geological mapping of Ellesmere and Melville Islands has proceeded at a favorable rate by the Geological Survey of Canada, with considerable support from the Polar Continental Shelf Project. The Beaufort Formation on Banks Island has been mapped; this formation was probably deposited prior to the development of the straits between the islands. Mapping of surficial deposits in the British and the Richardson Mountains upgrades previous work.

The potential usefulness of surface resistivity, selected borehole geophysical tools and seismic methods to detect, investigate and map surficial deposits in the permafrost environments was investigated.

A four-mile grid of gravity and bathymetric data was established at 982 stations in the Beaufort Sea, revealing gravity anomalies trending parallel to the coast or cutting the coast at a shallow angle. The northeastern sector of Victoria Island was covered by a gravity survey, revealing a relatively flat and featureless gravity field.

Continuous seismic-reflection profiling in the Mackenzie Delta, Eskimo Lakes, Liverpool Bay and continental shelf of the Beaufort Sea reveals existence of a discontinuous but very strong reflector which is believed to be the top of permafrost. This investigation is part of a continuing program to investigate the nature and areal extent of permafrost.

A unique co-operative program between six oil companies and three branches of EMR yielded valuable information pertinent to the sedimentary section and crust of the Sverdrup Basin. The attitude, nature and thickness of the various sedimentary strata overlying the basin have been mapped for one profile extending the length of the Basin.

SEARCH FOR AND EVALUATION OF RESOURCES

Search for resources. Many of the detailed studies carried out by the Geological Survey of Canada are directed to the search for non-renewable mineral resources.

A major project in 1972 was a regional geochemical reconnaissance by lake-sediment sampling of 36,000 square miles northeast of Yellowknife. The results of the survey were made available to the public in mid-April 1973 in the form of 21 maps at a scale of 1:250,000. Part of the area was also covered by an airborne gamma-spectrometry survey. This study, when made available to the public, resulted in the staking of 200 claims. Similar staking in the Mont Laurier area of Quebec resulted from a shared-cost airborne spectrometry survey carried out in 1971. Geochemical techniques were also applied in Newfoundland to outline areas of high potential in metallic mineral resources and thus to facilitate discovery by exploration companies. These studies were carried out for and in co-operation with the Newfoundland government.

Geochemical methods have proven very useful in mineral exploration, but different terrain conditions demand different techniques. The forested, non-permafrost part of the Shield, the area that contains the major part of our mineral wealth, has long defied the geochemist. During 1972, the Geological Survey continued a study into the use of organic gels as a sampling medium, and it is hoped that by 1973 it will be possible to present some conclusions that will be of assistance to those prospecting in the southern Canadian Shield.

Two major air-supported projects assisted in the evaluation of the potential of northern and arctic petroleum basins. Studies of the regional stratigraphy and structure of the Mesozoic rocks on Amund Ringnes, Ellef Ringnes and Cornwall islands were continued and the regional geological study of the Paleozoic rocks of western Devon Island was completed. A study of evaporite deposits in western Ellesmere Island was completed, as was a study of the stratigraphy and sedimentology of Paleozoic clastic rocks in northern Ellesmere Island.

One subdivision of the Geological Survey has as its objectives the determination of the character and distribution of mineral commodities in Canada, the understanding of the local and regional geological features conducive to the occurrence of specific types of mineral deposits and the application of data derived from such studies to provide qualitative and quantitative determinations of our mineral resources. During the report period, studies were done on copper, molybdenum, lead, zinc and the rare-earth elements. These involved field visits to many mining properties and mineral occurrences. Two maps (scale 1:500,000) indicating the copper and zinc potential of a 33,000-square-mile area in the Noranda-Val d'Or and Timmins-Kirkland Lake area were published. Three areas of high potential were outlined, none of which contained known deposits, but one south of Lake Abitibi has since been shown to contain a deposit (Magusi River) with an estimated potential of 3.74 million tons of 1.2% copper and 3.2% zinc — a result of great encouragement to those engaged in "Theoretical" predictions.

The Geological Survey, Mineral Resources

Branch and Mines Branch participated in a crash project with the code name Operation September to provide quantitative estimates of Canada's mineral endowment of copper, nickel, molybdenum, lead, zinc, uranium and iron. Although the department had successfully developed estimates for oil and gas, this new project required a different approach because of the many variables inherent in metal deposits. The task was completed within the time limits set and demonstrated the wide range of expertise available within the department.

Increased interest in the coal resources of Canada has been reflected in studies by the Geological Survey. Samples from the Upper Elk River, Crowsnest and Flathead coal areas of British Columbia and Alberta have been collected and studied. Staff members also participated in the joint federal-provincial coal-evaluation program in Saskatchewan which is designed to provide the geological framework needed to delineate areas of significant coal-seam development within the widespread Ravenscrag Formation.

The field aspect of a study of the mineral belt of central New Brunswick begun in 1971, which made use of existing mining-company geological maps, was completed.

Many of the studies carried out beyond our coasts are directed to an evaluation of potential resources. Geological Survey officers continued detailed and regional surface and subsurface studies in the Hudson Bay Basin and began subsurface stratigraphical investigations of the Mesozoic and Tertiary rocks of the Atlantic Continental Margin Basins. The results of the latter study indicate at least two areas containing sedimentary sequences capable of generating and retaining large volumes of hydrocarbons.

To assist agencies involved in resource development, geophysical data collected on cruises by the Bedford Institute prior to 1972 are being published as "natural resources charts" at a scale of 1:250,000.

Studies in the use of glacial till as a sampling medium for prospectors were continued and samples were collected in the Thetford Mines-Lac Mégantic region, an area containing ultramafic rocks that carry identifiable nickel and chromium values.

In support of the search for and evaluation of resources, the Geological Survey participates in energy-resource evaluations for the sedimentary basins of western and northern Canada. Studies were carried out in the fields of organic and inorganic geochemistry, clay mineralogy, coal petrology and petroleum geology. The Geological Survey maintains at its Institute of Sedimentary and Petroleum Geology cores, samples and logs of northern wells and also a library of confidential and non-confidential company reports and maps covering geological and geophysical work done in the northern territories. This valuable collection is of great assistance in evaluation studies.

Several members of the Geological Survey took part in the department's Second Annual Evaluation of the Petroleum and Coal Resources of Canada. This provided, for the first time, a realistic appraisal of the nation's fossil-fuel resources based on strictly geological parameters derived in large measure from the results of the Survey's detailed analysis program of the sedimentary basins of Canada.

Evaluation of fuels and other resources. Pursuant to an announcement by the Minister in September 1972 that the department would undertake a long-term assessment of Canada's oil and gas resources, the department's Energy Sector, the Geological Survey, and the Department of Indian Affairs and Northern Development have begun to collect a body of data and a preliminary analysis on these fuels. Continuing data-processing and analysis will permit annual updating and refinement of the appraisal of Canada's total oil and gas resource potential. As part of this program, an up-to-date inventory is being maintained by EMR of proven petroleum reserves and potential resources in the sea-covered areas of Canada. This inventory uses data from the petroleum industry submitted under the regulatory system administered by Indian Affairs and Northern Development and EMR, and from studies carried out by the department itself. Its purpose is mainly geological analysis and economic evaluation of potential hydrocarbon reservoirs in the frontier regions.

Canada's knowledge of its coal resources is limited to a general geological description and an assessment of the quantity of coal below ground, subject to minor recovery criteria. In such terms, the coal resources are large; but the recoverable amounts are much less, owing to difficult underground access. The department is developing the methodology for evaluating coal resources in terms of recovery and economics. The methodology is designed to remain unaffected by changes in mining and combustion technology.

In connection with a study being conducted by the Organization for Economic Co-operation and Development (OECD), members of the department have re-evaluated Canadian uranium resources and predicted demand for uranium to the year

2000. They found that reasonably assured resources of uranium, exploitable at not more than $10 per pound of uranium oxide (U_3O_8), amount to 241,000 tons. Another 158,000 tons could be mined at $10 to $15 per ton. The experts believe that a further 530,000 tons is available at up to $15 per pound.

At present, approximately 75 per cent of Canada's electrical energy is generated by hydroelectric stations. This is a substantial saving in fuels: at current levels of thermal-power efficiency, nearly 70 million tons of bituminous coal would be needed each year to produce the same electricity. This would nearly triple Canada's coal consumption.

The share of hydroelectric stations in the production of electric power is expected to decline. Estimates of future fuel needs for power production also require better knowledge of usable hydro resources. An assessment of these resources, bearing in mind economic and environmental constraints, is now being carried out by EMR, in conjunction with provincial organizations.

In recent years, it has been suggested that more ore is being used up by Canadian consumption and exports than is being found in Canada and that ore-discovery costs have greatly increased. Research within the Mineral Resources Branch has shown that, on the contrary, Canada has been adding to its net mineral reserves and that, although discovery costs have risen, the increase has not been as steep as is widely believed.

As part of a departmental study, estimates are being made of as yet undiscovered mineral deposits, on a regional basis, in terms of tonnage, grade, and ore types; this is done on the basis of geological indicators and experience. From these estimates, impression of future mineral production, capacity, employment and income are being evolved, both for known and as yet undiscovered mineral deposits. For planning purposes, various supply patterns are being simulated to meet forecast mineral requirement, in order to gain insight into the question of where, and at what rate, mineral capacity might best be developed from a national point of view.

A contribution was made to a study by the Ministry of Transport on the best route for constructing a railway extension in British Columbia toward the Yukon border. Estimates were supplied of the quantities of minerals that might be transported along such a railway extension, both from mineral deposits now known and from deposits that may be found and developed in the near future.

The objective of the National Mineral Inventory, a major component of EMR's data base, is to identify, describe and evaluate information on all known mineral occurrences in Canada. The inventory consists of a comprehensive summary of location, geology, history of ownership, development and results of development supplemented by map and literature references, on each occurrence. It has been estimated that some documentation exists on about 30,000 occurrences in Canada, and of this number more than half are now recorded in the inventory. The summaries are available to industry and the general public as well as government, and to facilitate reference to them they have been indexed and included in the Canadian Index to Geoscience Data, a publication of the Canadian Centre for Geoscience Data.

Tests and analyses. Departmental experts also carry out a broad range of tests and analyses, in field and laboratory, on the suitability of Canadian fuels, ores and other non-renewable resources for modern industrial processes. Such work is done chiefly in the Mines Branch.

The properties and location of Canadian coals and ways and means of preparing them for specific uses again claimed a major share of this work.

The mountain coals of Alberta and British Columbia represent more than 70 per cent of the geologically estimated coal reserves of western Canada. However, the assessment of the economically recoverable portion of that coal presents serious problems, as the coal seams are thick and/or inclined and accessible only through underground mining. Current underground methods do not work satisfactorily in such seams, and new methods needs to be developed. By studying progress made in other nations, especially France, EMR engineers have begun to tackle this problem.

Gas outbursts and ground-control problems also limit the mining of some coal seams. Conditions causing such dangers and means of preventing them are being studied, with some positive results.

As part of a joint federal-provincial program to obtain a more accurate assessment of lignite resources in Saskatchewan, a drilling project was launched. More than 200 holes were drilled, totalling 100,000 feet, in the areas of Estevan, Willow Bunch, Wood Mountain and Cypress Hills. The work was completed during the 1972 field season. In the next season, the areas known to contain coal will be drilled more closely to obtain a more precise estimate of commercial quantities.

More than 2,000 coal samples were analyzed. Progress is being made in the data-processing of this project, though many improvements remain to be made.

A considerable advance was made in the study of the chemistry of coking coals as a means of resource evaluation.

The Mines Branch's coking laboratories at Ottawa maintained a high level of coking tests, evaluating coals being mined in British Columbia and Alberta, chiefly for export. The coking characteristics of each major coal deposit must be determined before its value can be calculated and a marketing agreement negotiated.

To help the coking industry of Canada, Algoma Steel Corporation donated a gas-fired movable-wall oven to the department. The oven is being installed in the EMR laboratory at Edmonton, Alberta, in space rented from the Research Council of Alberta. It is expected to become operational in mid-1973, and should give improved service in coking tests to western coal producers, with costs to be shared. Petrographic and other laboratory studies of coals, however, will continue in Ottawa, for the sake of continuity and coherence.

Mineralogical and analytical tests were carried out on a group of coal samples from the Lingan area of Nova Scotia to elucidate sulphur distribution in that high-sulphur coal.

The characterization of non-metallic ores continued during the year, particularly the long-term study of the composition and properties of ceramic clays and shales in Canada. A report on typical clays and shales of the Atlantic provinces is at the editorial stage. Ceramic properties of typical common clays and shales from the Prairies were determined and studies of their mineralogy were started. Tables of properties of many clays and shales evaluated in the past sixty years are being assembled by regions in English and French. These will be used in a comprehensive monograph of the properties and occurrence of Canadian clays in relation to their possible use in ceramics.

Other extensive evaluations were made on the properties and development of uses for asbestos fibre; on the properties and usefulness of clay fly ash mixtures from Edmonton for firebrick; on chemically prepared magnesia from Quebec and magnesite from British Columbia for use in refractories; on a talcose rock from British Columbia for various commercial applications; two Canadian granites from Quebec, two marbles and one chalcedonic agate from Ontario and a travertine rock from British Columbia were assessed for their potential as building stone; an information circular was published entitled Canadian Minerals for Refractories; and many meetings were attended by a departmental representative to discuss new uses for Canada's large sulphur surplus and to establish a Canadian Sulphur Development Institute.

Studies, some completed and others in progress, have been conducted of the mineralogy of various areas of Canada to assess their ore deposits and means that could be used in beneficiating those ores that appear sufficiently attractive, economically, to be worth developing. Among the studies that were started in the fiscal year 1971-72 and have continued into 1972-73 are the large porphyry copper-molybdenum deposits in the Highland Valley and adjacent areas of British Columbia. This investigation is aimed at identifying the minerals and their relationships, thereby characterizing the features that would be of importance in beneficiation. A study of the platinum-bearing placer sands in the Tulameen River area of British Columbia seeks to characterize the platinum minerals present, to determine their mineralogical associations and to elucidate the mineralogy of the river sands. Ten platinum-group minerals have so far been identified, of which at least two are new minerals. An investigation has been started of the base-metal occurrences in the Sturgeon Lake area in the Kenora mining district of northwestern Ontario. This investigation is aimed at determining the mineral assemblages, their textural relationships, and their chemical characteristics. A study is also being made of the complex tin-bearing minerals found in the Mount Pleasant area of southwestern New Brunswick, and of the phase relationships that govern the natural assemblages of this series of minerals.

ECONOMIC AND SOCIAL ASPECTS

ECONOMIC PLANNING AND MARKET ANALYSIS

Growing domestic need for all forms of energy and the expanding opportunities for the export of any available surpluses to countries deficient in energy has raised a number of important political, technical, and financial questions. The enormous capital expenditures Canadian energy producers would have to make to satisfy expected domestic and foreign demand could strain Canada's financial capacity. These capital needs and the growing concern over Canadian ownership of energy resources, along with environmental and social factors have an important bearing on the development of a Canadian energy policy.

To provide the basis for such a policy, the federal government embarked on a series of special studies in 1971; these continued throughout 1972 and into 1973. The first product was to be an analysis of Canada's energy situation, scheduled for release in the summer of 1973.

Oil. Particular attention in the analysis of the petroleum situation in Canada is being paid to establishing deepwater ports in eastern Canada, and setting up related petroleum refineries. Eastern Canada has a number of excellent sites for deepwater ports, which is significant with the trend toward very large tankers for shipping crude oil. Such natural port sites are lacking on the eastern seaboard of the United States, and Canadian ports might therefore serve as transshipment points. Refineries are also being planned for Canadian port areas to serve North American markets.

Such proposals call for a reassessment of Canada's National Oil Policy, which so far reserves the area west of the Ottawa Valley for domestic petroleum.

Since oil and gas provide more than two thirds of Canada's energy, the department is studying a series of related matters, such as: the upward pressure on Canadian prices by higher prices in the United States; the desirability of a two-price system; security of supply from foreign sources, together with alternative and emergency measures; the management of the international petroleum market; and federal-provincial relations in the field of oil production and marketing. The department also arranged exchange visits with oil and gas officials of the Soviet Union and China. The technical exchange with the Soviet Union was initiated in 1970, and that with China in the fall of 1972. The latter began with a visit of China's petroleum experts to Canada, and a return visit of Canadian specialists to China led by the Minister of Energy, Mines and Resources in the spring of 1973.

Coal. Studies of a similar nature are being conducted on Canada's coal supply. Since this matter is closely connected with mining, economic and political development in other countries, a series of studies was begun of coal developments in Australia, China, and the European Economic Community.

A comprehensive study was undertaken of increased employment in Canada through the mining and processing of metallurgical coal. Private companies and provincial governments contributed to the study and were provided with the results.

The economics of the coal market in comparison with those of other energy sources were studied, since any fluctuations in the latter may cause abrupt changes in the supply of coal and, in certain circumstances, coal shortages.

Uranium. Studies related to the feasibility of a uranium-enrichment plant which had been initiated in the previous fiscal year were continued. Although considerable effort is being made throughout the world to develop a centrifuge enrichment process, Canadian studies have been related to the gaseous diffusion process used in the United States. Much of the technology required for such a facility is in the hands of foreign governments. Therefore, if private industry in Canada were to embark on this endeavor, the government would need to be involved in the negotiations for the release of the data and for its subsequent safeguarding. The product from an enrichment facility would be destined primarily for export, in line with the objective of the further processing of uranium, since Canadian reactors are fueled with natural uranium.

Requirement and economics of heavy-water production were evaluated and discussed. Heavy water is an essential ingredient of the CANDU type of nuclear reactor used in Canadian nuclear power plants. Unless there is an adequate and assured supply at reasonable price, it will be impossible to pursue the Canadian nuclear power program envisaged by Ontario Hydro and other utilities.

Electrical energy. To safeguard and improve this traditionally valuable source of energy in Canada, the department is encouraging technological developments, interconnections between regions and, where appropriate, it is making financial contributions to projects with long-range benefit or significant economic risk.

While exports of electrical energy to the United States are modest, amounting to about 3 per cent of Canada's total generation in 1972, substantial benefits can be derived from cross-border exchanges. These, of course, must be subject to safeguards to prevent cost increases and supply shortages in Canada. Although no specific expansion of generating capacity has occurred to meet export requirements, construction schedules may be speeded up, and some money saved, if there are short-term opportunities for interprovincial or international power sales. Seasonal differences in demand patterns may also create opportunities in this market.

Economic studies. The broad economic studies of the department's Energy Sector included a forecast of Canada's energy demand to the year 2000, of relationships between energy development and use and employment, energy costs in the Canadian economy, possibilities of upgrading energy exports, Canada's position as a world energy source and user of energy, state participation in energy production, etc.

Progress was made during the year in setting up a data bank on energy, a computerized system for storage and retrieval of statistics. The data bank provides detailed financial and corporate information on the energy and associated industries not available elsewhere.

All these economic studies were to form the basis for the energy analysis slated for publication in 1973-74. They also helped the Energy Sector to discharge its functions of advising the government on energy policy and of keeping the Canadian public informed in this vital field.

Mineral commodities. The effect of the mineral industry on the economy of Canada -- how much employment it generates, what its influence is on foreign trade, what its ramifications are for other industries, etc. -- has been little understood in the past. It is now a subject of intensive investigation.

The Mineral Resources Branch has become familiar with the very large medium-term econometric model of the Economic Council of Canada, referred to as the "Candide" model. With it forecasts were made and simulations run that will throw light on what the mineral industry may look like and what part we can expect it to play in the Canadian economy in 1980.

Longer-range work included the development of mineral-supply and -demand forecasts to the year 2000. This picture of the future, of mineral markets, international competition, and the share of world production and consumption that Canada may expect in 20 to 25 years helps in deciding what actions should be taken now. Lastly, tests were made of long-term world models. For example: "World Dynamics" is a method for making very long-range forecasts of social and economic systems, using the computer to keep track of all the interrelationships within these systems. The Mineral Resources Branch has monitored research developments in this field and conducted its own research owing to the importance attached to non-renewable resources. Work has been done on the "Limits to Growth" world computer model, and a smaller Canadian model was developed for the department at the Massachusetts Institute of Technology.

It was concluded that although the Club of Rome had brought before the public the spectre of overcrowding, pollution and resource shortage, its method of modelling was overly simplistic. It was further believed that the models were not useful at this time in Canadian government decision-making. Further studies are in process on the methods of World Dynamics, and a lengthy critique was scheduled to be published in 1973.

A delegate of the department participated in the deliberations of the Lead and Zinc Study Group, which seeks to stabilize international lead-zinc markets and to reduce barriers to trade.

A departmental mission, led by the deputy minister, visited Poland in order to acquaint itself with the production of metals and minerals in that country, and to seek information on the hydraulic mining of coal, which holds out important advantages to Canadian coal mines. The department, in co-operation with the Department of Industry, Trade and Commerce, sponsored a joint mission to China in November and December 1972.

The department provides an alternate delegate to the International Tin Council on an ad-hoc basis. Tin has been the most closely controlled metal in international trade.

During the fiscal year, arrangements were made for interested departments to participate in the preparations for the negotiations under the General Agreement on Tariffs and Trade (GATT), which were expected to begin in 1974. EMR named an assistant deputy minister to represent the department in an interdepartmental committee, and arranged for other personnel to begin work on the preparation of background data.

A world oversupply of potash continues to plague the industries based on this Saskatchewan resource. In order to plan for the future, the Mineral Resources Branch undertook a study of potash production, concentrating on provincial revenues and industry profits to 1980 and analyzing the effects of existing regulatory schemes and alternative measures.

A federal-provincial drilling program led to the discovery of a potash deposit in New Brunswick. EMR was called on to give advice on the development of the deposit in the light of difficult world market conditions.

A study is being carried out concerning the regional impact of a proposed copper smelter in the Clinton area of British Columbia, particularly with respect to jobs and purchase of locally made equipment. Two different smelting processes are being analyzed against this background.

Mining taxation. The department continued to provide advice to the Department of Finance on the taxation of the mining industry. Modifications were recommended of the amended Income Tax Act, which came into force in January 1972. Assistance was also given in revising regulations under the amended act.

Numerous requests were received from members of the mining industry for clarification of the Income Tax Act and Regulations, as well as for help to bring about amendments in the act. A review was made of the comparative effects of corporate income taxes in Canada and Australia on the mining industry of the two countries.

The Department of National Revenue is continuously advised on the administration of those parts of the Income Tax Act and Regulations bearing on the mining industry, such as the three-year exemption of new mines and the percentage depletion allowance. The Department of Justice is assisted in court actions arising from the recommendations.

REGIONAL AND SPECIAL PROGRAMS

Under this heading, the department reports chiefly on activities designed to benefit certain Canadian regions that are in need of economic development or that merit special research because of their peculiar geography. Foreign-aid projects are also reviewed.

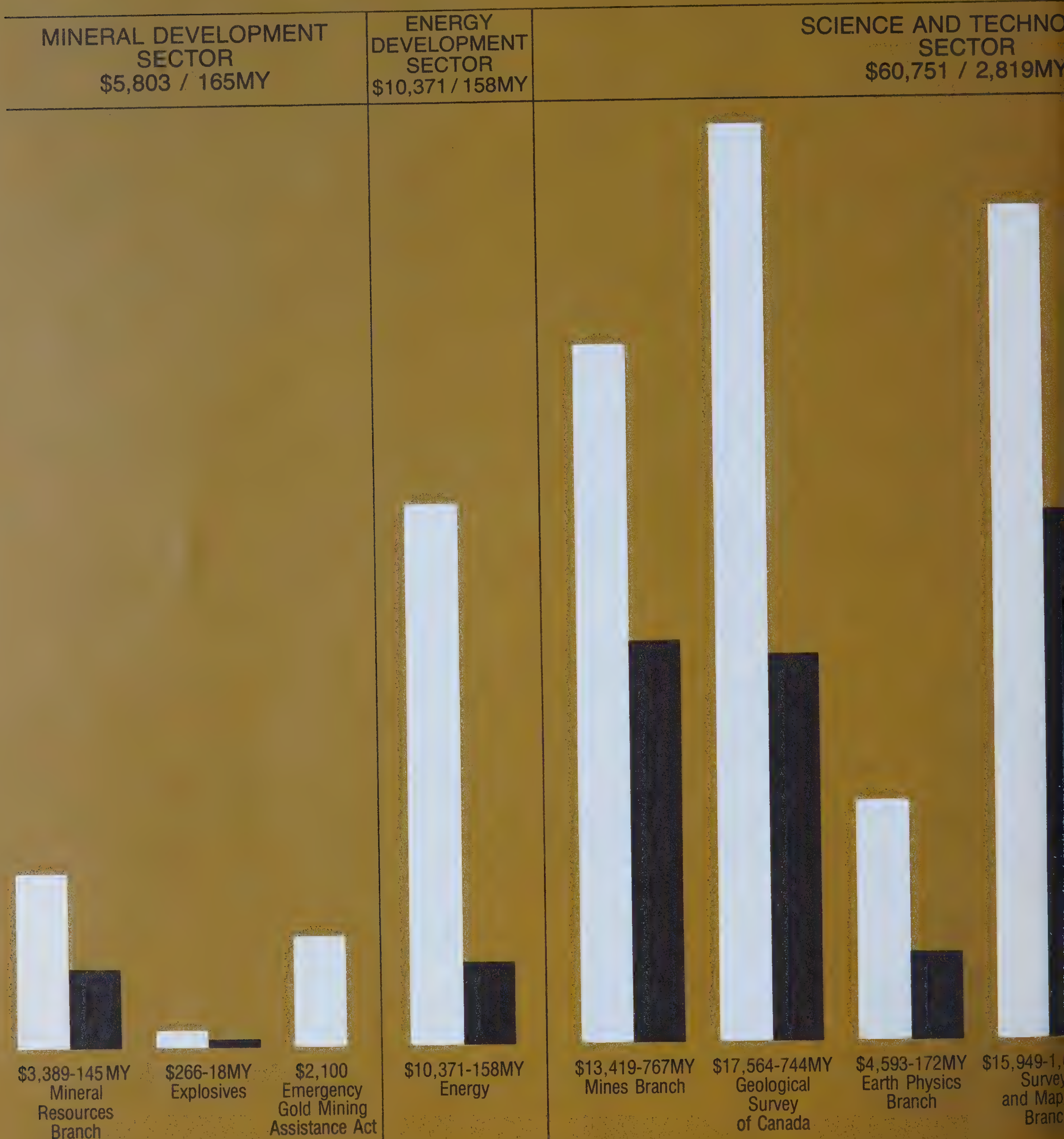
Petroleum and other energy sources. Of the regional and special programs related to oil and gas, the department has been giving particular attention to the Task Force on Northern Oil Development. This interdepartmental committee, under the chairmanship of the Deputy Minister of Energy, Mines and Resources, was established by the federal government in December 1968, to give advice on all matters relative to northern oil and gas development and transportation. EMR's Energy Sector serves as co-ordinator for the work of the Task Force and its six subcommittees: environmental and social, economic impact, pipeline engineering, transport, marketing, and industrial supply. Pipeline guidelines in principle, based on recommendations of the Task Force, were established by the government in August, 1970. Draft environmental and social guidelines were published in June 1972. Consideration is now being given to guidelines concerned with financing, ownership and the Canadian content of northern pipelines. The Task Force environmental-social program is now entering its third year of a four-year $20-million program. This program and other Task Force projects are designed to provide background information and baseline studies on all matters that will have to be appraised when an application to construct a northern pipeline is received by the government.

To provide information and advice concerning the financing of a northern pipeline, which would involve expenditures of at least $5 billion, the Minister of Energy, Mines and Resources established a National Advisory Committee on Northern Pipeline Financing in 1972. This committee is made up of senior representatives of the financial community in Canada. Its findings will help to define guidelines for the financing and Canadian content of a northern pipeline.

Panarctic Oils Limited, a consortium in which the federal government has a 45-per-cent interest, was established in 1968 to carry out oil and gas exploration in the region of the Arctic Islands. The exploration has had very encouraging results. The extent of Panarctic's

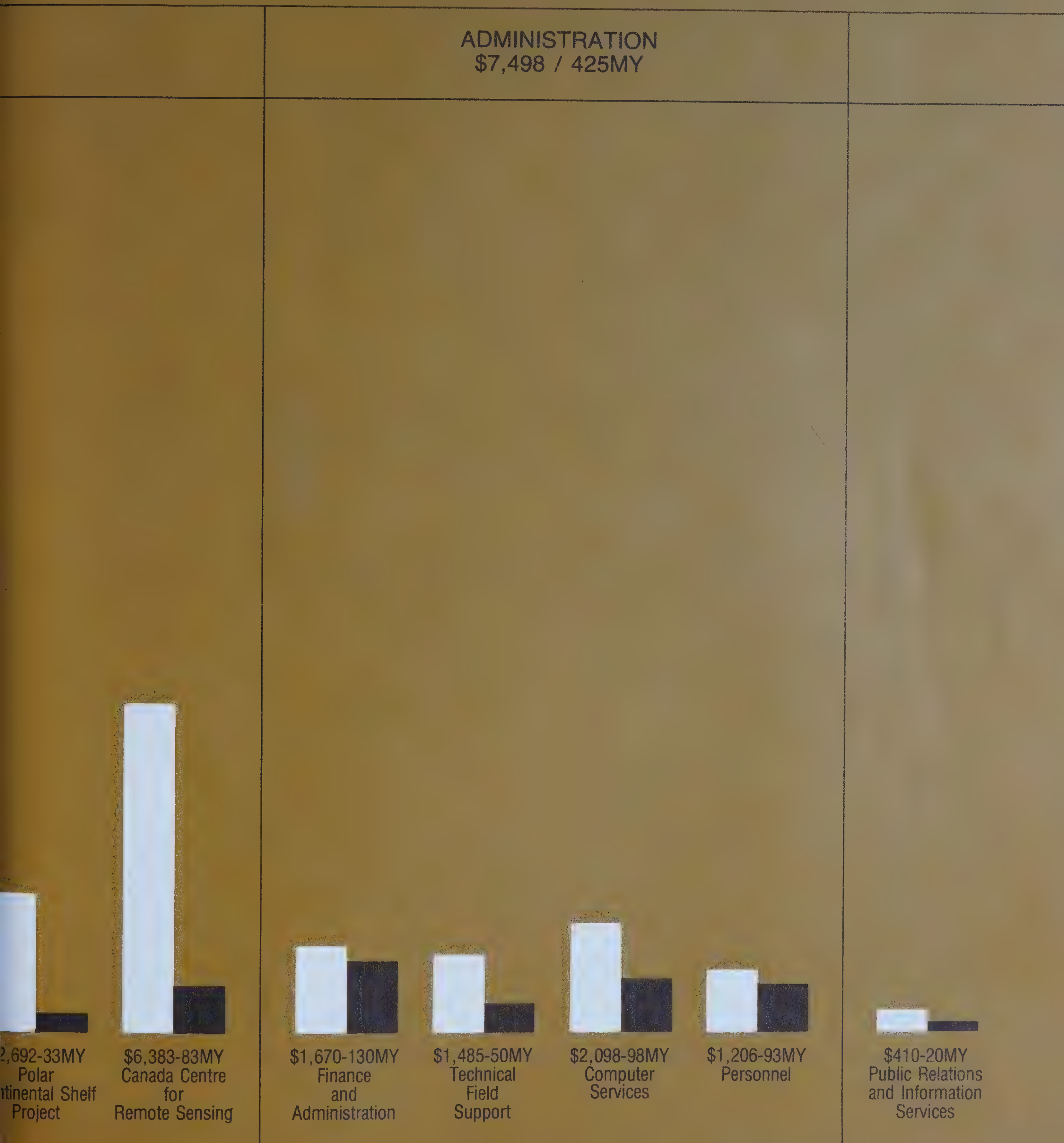
DEPARTMENT OF ENERGY

1972-73 ESTIMATES IN THOUSANDS OF DOLLARS AND MAN



MINES AND RESOURCES

RS / TOTAL FOR DEPARTMENT: $84,423; 3,567 MAN YEARS (MY)



success in opening up the Arctic Islands gas and oil potential will determine in considerable part the future development of northern Canada. Initial appraisals are now under way on pipeline-route possibilities for Arctic Islands natural gas. The government's representation in the Panarctic consortium provides a means of encouraging the development of Canada's northern oil and gas resources and of northern Canada as an economically viable region. The government's future role in Panarctic is being assessed to determine how the company may best serve the national interest in opening up the resources of a region that is considered to be one of Canada's most important potential sources of hydrocarbons.

Policy recommendations and advice are provided on a number of offshore matters that have economic and social implications at the regional level. In the negotiations between the federal government and provincial governments, in particular those of the five eastern provinces, regarding offshore mineral rights, policy advice has related to the manner in which those rights should be made available for development, the manner in which they should be administered, and the allocation of offshore mineral-resource revenues. There has also been participation in studies especially concerned with the importance of ensuring that Canadian industry in general, and that of the coastal provinces in particular, will benefit as fully as possible from the exploration and development of our ocean resources, including energy resources.

The department continued to advise the Cape Breton Development Corporation, particularly on improving coal productivity and marketability. The Corporation has important regional responsibilities relative to the Nova Scotia coal industry.

The joint venture between the federal government and Denison Mines, begun in 1971, to stockpile uranium at a rate of two million pounds a year, continued throughout the fiscal year. This has permitted continuation of Denison's Elliot Lake operation at an economically viable level. In November 1972 a sales agreement was made with several Spanish utilities for the delivery of approximately nine million pounds of uranium from 1974 through 1977, at a total value of about $60 million. Some six million pounds will come from the joint Canada-Denison stockpile and will exhaust that stockpile. The other three million pounds will come from the general government stockpile accumulated during the period 1963-70 to maintain production in the Elliot Lake area. The stockpile programs were essential to maintain uranium mining until marketing prospects improve.

In the area of federal-provincial liaison and agreements, the Energy Sector is involved in a number of specific activities. The Nelson River Transmission Agreement between Canada and Manitoba, under which Atomic Energy of Canada Limited has built a high-voltage direct-current transmission line with terminal equipment rated at 1,080 megawatts, has reached the point where all the basic equipment requirements of Phase 1 have been placed on order. The Energy Sector provides the chairman for the Nelson River Agreement Review Committee. Since the Canada-Manitoba agreement contemplates its extension to cover additional converter terminal equipment up to the ultimate rating of 3,200 megawatts, discussions are in progress with Manitoba concerning the specific terms of a new agreement.

The department acts as co-ordinator in federal-provincial discussions relating to the James Bay regional development. Useful progress has been made in resolving a number of aspects relating to the environment, transport, communications, etc. The principal and most difficult problem of native people's rights remains unresolved and has been the subject of litigation before the Quebec Superior Court.

Interest in interprovincial electrical-transmission connections was focussed during the year on the Maritimes with discussions of a federal role in interconnection between Prince Edward Island and the mainland and in reinforcing the existing New Brunswick-Nova Scotia interconnections. These activities involve close co-ordination with the Department of Regional Economic Expansion.

Assistance was provided to the Province of Newfoundland in preparing the "energy section" of its economic development plan and also to Ontario's Task Force Hydro on matters concerned with rates and costing.

A review of the technical and economic aspects of Bay of Fundy tidal-power development is under way. This was studied in detail by the Atlantic Tidal Power Programming Board and reported on in 1969. A federal-provincial group is currently re-examining the 1969 conclusions which were that a Bay of Fundy tidal-power development would not be economically competitive with alternative sources of electrical energy.

In the international field the department has had a major role in the exchange of visits and technical information related to energy under the Canada-USSR Agreement for co-operation in

Industrial Technology. This has led to an improved understanding of areas of common interest. Better opportunities for economic co-operation in the oil, gas and electric-power fields which will be of benefit to both countries are being sought. A program of exchange visits on energy matters is also under way with the People's Republic of China.

Mineral development and exploration. The department seeks to further the use and processing of mineral resources in regions of the country that have lagged in economic development. Such development, where practical, can yield important economic and social benefits that diffuse throughout the region.

At the federal level, most of such development work is undertaken in conjunction with the Department of Regional Economic Expansion. Projects are being carried out in Newfoundland, Cape Breton Island, the mainland of Nova Scotia, New Brunswick, Gaspé, the Lac Saint Jean region of northwestern Quebec, and the gold-mining communities of northern Ontario.

The department's Mineral Resources Branch carried out a Mineral Area Planning Study (MAPS). It was designed to develop the framework for decisions on mineral resources in various areas, to examine the location of communities dependent on mineral resources, and how population, employment and income will change through time. MAPS has also analyzed the changing structure of the mineral industry: the proportion of commodities, the technology of mineral transportation, mineral processing. These factors significantly affect the regional expansion of Canada's mineral industry.

Railway construction in northwestern British Columbia continued in 1972-73, opening very favorable opportunities for mineral and forestry development. The department co-operated with the Ministry of Transport by upgrading its assessment of mineral potential and expected timing of development. The groundwork for a comprehensive regional development plan has been laid.

An extension of the New Brunswick co-operative agreement was prepared and implemented during the year. These activities have assisted in locating a significant potash and salt deposit in New Brunswick.

An amendment was enacted to the Emergency Gold Mining Assistance Act (EGMA), extending the life of the act to June 30, 1976, without change in the method of computing financial assistance.

The Geological Survey is responsible for the federal-provincial aeromagnetic surveys. Two contracts were completed during the year, one in British Columbia and one in northern Baffin Island. Another contract was initiated in Quebec (Ungava Peninsula). Good progress was made toward completion of four other existing contracts. More than 170,000 line miles were flown and 261 aeromagnetic maps were printed and published.

A unique and successful co-operative project involving industry and government was carried out in the Arctic Islands in the spring of 1972. Six oil companies participated, with the Geological Survey as operator, in a reconnaissance refraction-seismic profiling along a survey line between Melville Island and Amund Ringnes Island. In addition, a series of large explosions were detonated in support of deep crustal surveys by the Earth Physics Branch.

Two experimental high-sensitivity aeromagnetic surveys in the Kirkland Lake and Bathurst areas were shared with the provinces of Ontario and New Brunswick respectively, and a series of airborne gamma-spectrometer flights were made in collaboration with the Department of the Environment and various agencies of the province of Ontario to measure snow-water depth.

Foreign aid. The department provides technical advice and experts to developing nations through the Canadian International Development Agency. It also co-ordinates training courses for nationals of developing countries in disciplines related to EMR's mission.

In 1972-73, the Mineral Development Sector arranged 26 training programs and gave advice on technical assistance to copper mines in India and a lead-silver mining project in Burma. Geologists directed and co-ordinated various projects sponsored by CIDA. Aeromagnetic-radiometric airborne surveys were carried out in Niger, Cameroon, Upper Volta and Guyana. A geologist was seconded to the Omo River Project in Ethiopia and another was loaned to the government of Bolivia. A three-man geological survey team was sent to Brazil to advise on a proposal for the investigation of the Goias region. Advice on topographic surveys was given in Tanzania, Ghana, Kenya, and Guyana. Professional personnel from the department contributed to technical seminars in Indonesia and Brazil.

Arrangements were made for the Canadian representation to the third session of the United Nations Committee on Natural Resources, which was held in New Delhi, India, in February 1973.

TECHNOLOGY AND ENVIRONMENTAL CONCERNS

TECHNOLOGY

A large share of the research carried out by the department is aimed at increasing the level of technological effectiveness in Canada. Because of EMR's mandate in the field of non-renewable resources, such research is concerned chiefly with mine safety, the concentration and beneficiation of ores, the processing of fuels to a marketable state, metallurgy, the methodology and instrumentation used in various geological, geophysical and topographic surveys, etc. Every year, Canadian companies active in the resource field benefit from technological advances produced by EMR research, and the work of the department itself progresses through continuous innovation.

Patterns in fuel technology. EMR's responsibilities in the field of oil and gas include recommendations on the type of research that should be conducted to develop and conserve these two resources. Special attention is being paid to the heavy oils, including the Athabasca oil sands. Advancements in technology have an important bearing on the economics of oil extraction, which is particularly important in the Arctic and the offshore as well as in the Athabasca oil sands. The department is also co-operating with the Science Council of Canada in a review of such research.

The stringent requirements imposed on offshore exploration to ensure that it is carried out safely and does not pollute the environment have prompted the oil industry to develop new technology to meet government standards. This applies particularly in ice-infested waters such as those off northwest Newfoundland and Labrador, where drilling proposals by industry were under review during the year.

Not all of Canada's coals can be economically extracted with present mining techniques. Particularly difficult to mine are thick, steeply pitching seams, which present a danger to miners. The department is examining techniques used for such seams in older coal-producing nations to see whether they would be applicable in Canada.

Departmental experts have kept a continuing review of the performance of the Canadian-designed CANDU nuclear power plants and power plants of other countries. The excellent performance of the Pickering station has confirmed the suitability of the CANDU design for Canadian conditions. The specialists have concluded that it would be premature for Canada to embark on extensive research on reactors of the fast-breeder or thermonuclear type. They believe that the flexibility of the CANDU reactor and its ability to use thorium as well as uranium fuel mean that this type of reactor will continue to be an efficient and competitive energy source for several decades, even if the fast breeder is developed commercially elsewhere.

The Research Institute of Hydro Quebec (IREQ) has received loans and grants from the department to carry out research that would advance power-transmission technology throughout Canada. The institute became operational during the year, and most of the facilities provided for by the federal-provincial agreement are in place.

Contacts are maintained with the Canadian Electrical Association, especially in areas studied by the association's Research Committee and Environment Committee. These committees seek to find ways and means for industry and government to co-operate on research projects.

Automation in surveying and instrumentation. Although map-making in EMR's Surveys and Mapping Branch has kept pace with technological advances in that field and the output is now much higher than ever before, there is always room for the introduction of new labor-saving devices. The "Automated Cartography Project" entered its production-development phase in 1972. Time on the system was shared between production of 1:50,000 maps and further development. A block of 1:50,000 map sheets in the Yukon Territory was assigned for production by automated methods.

Additions to computer hardware, aimed at achieving a fully operational level in 1973, continued. With the assistance of Waterloo University, work began on cartography software.

Agreement was reached between the Surveys and

Mapping Branch and the Geological Survey of Canada for the establishment of a digitizing station in the Geological Survey to operate on-line with the Automated Cartography system.

Automation through the use of computers also took further strides in the research of the Earth Physics Branch. Instrumentation in the field of gravity research was improved. The Seismology Division commissioned for program development a mini-computer and a data-acquisition system which will provide on-line detection, location and identification of seismic events at the Yellowknife seismic array. The new system will be installed in a new laboratory at Yellowknife and will begin operation in 1973-74. (The array is capable of detecting underground nuclear explosions in other parts of the world.) Design work was completed and a start was made on the procurement of equipment for an Ottawa-based telephone-linked seismic system to permit rapid location of earthquake epicentres in eastern Canada.

Improvements in methodology and instrumentation were also made in the Geological Survey of Canada. High-resolution aeromagnetic surveys with a complex variety of instruments were carried out experimentally in the Kirkland Lake area and in New Brunswick. New methods of exploring the geochemistry of the sea and the geology of the sea bottom were tested.

Metallurgical technology. A number of investigations were again carried out in the field of physical metallurgy to test the performance of metals and alloys in Canadian environments. One of these concerned improvements in measuring the toughness of pipeline steel; another the improvement of welding technology; still another the development of non-polluting moulding mixtures for foundries. Criteria were drawn up for the reduction of brittle failure in cast-steel propeller blades for icebreakers. Experiments in improving the superplasticity of steels produced a steel which could be stretched to three times its original length in a single operation.

Hundreds of requests were received for information, assistance and advice on questions arising from the processing and use of metals and alloys, which were dealt with by telephone, letter, or tests. These requests originated with industrial companies, research institutes, and government departments.

The department's Physical Metallurgy Division acts as examining authority on behalf of the Canadian Government Specification Board for certification of personnel qualified to carry out nondestructive tests. During the past 12 months, 624 persons were examined at 27 test centres across Canada.

Hydrometallurgical processes, unlike conventional pyrometallurgical processes, allow metals to be recovered from sulphide ores without the discharge of noxious sulphur dioxide into the atmosphere. From an anti-pollution standpoint, hydrometallurgical processes are therefore preferred, and the department has been developing such a process that could be used on ore concentrates containing copper, nickel, cobalt and iron. The process had the advantage that it could be used at deposits smaller than that of Sudbury, for example, where conventional metal-producing complexes would be uneconomical. The sulphur is recovered in pure form, and may thus even have a market value. The process has a variety of possible applications, and some of the technology in it has already been used commercially.

New technology was introduced in the construction of a compression-testing machine that is capable, under stringent controls, of reducing a cylindrical metal specimen's height by 50 per cent. From such tests, accurate calculations can be made of the force needed to perform hot-metal forming.

Ore treatment. One of the techniques used by the Canadian mining industry to separate metal from other ore minerals is flotation, in which tiny metal particles are borne up in a froth and are skimmed off the gangue. Various sophisticated experiments are being carried on in the department's Mines Branch to improve flotation technology. Also under study is the floatability of non-metallic minerals, such as nepheline syenite, diopside, zircon, marl, graphite and special silicas.

Research continued on the chemistry of flotation pulps, in which copper and cyanide salts are used to modify the floatability of copper and other metal sulphides. A new flotation reagent was developed for the flotation concentration of scheelite, a tungsten mineral, and a patent was applied for.

The flotation process for antimony ores of New Brunswick was improved greatly by the discovery of new depressants for the iron and arsenic sulphides that interfered with antimony concentration. Using this new process, an idle antimony mine returned to production.

The production of high-purity iron-oxide concentrates suitable for direct production of steel by rolling and annealing was achieved on several samples of hematite concentrates. The process is being evaluated by an industrial firm.

The department continued to advise on and perform laboratory work for the development of a new fluorite-barite deposit at Lake Ainslie and the improvement of a new mine operation at Loch Lomond, both in Cape Breton, and for the concentration of celestite and the development of a processing plant for spodumene at Bernic Lake, Manitoba.

A method of recovering metallic silver from off-grade silver concentrates from silver mines at Cobalt, Ontario, consisting of grinding and screening, was found to be more efficient than the traditional method of melting or chemical extraction.

Experiments continued on the on-stream analysis of ore and coal slurries, which would greatly speed up processing.

Fuel technology. As in previous years, the work of the department's Fuels Research Centre has concentrated on beneficiating low-grade petroleum, i.e., the removal of sulphur, oxygen and nitrogen and the conversion of a large part of the asphalt fraction to oil. Significant advances were made in improving the mechanical aspects of the pilot plant. The yield of oil and gas to be expected from the Athabasca tar sands can now be predicted more accurately, and the environmental constraints of the refining process are better understood.

To help mining companies to design tall smoke stacks, which disperse noxious smoke more effectively, a study of smoke-plume dispersion was started in 1969 with the participation of private, provincial and federal agencies. Various types of geographic regions have been selected for study. It has been found that experience accumulated in other countries cannot be confidently applied in Canadian conditions. During the past year, eight plume dispersion studies were completed and circulated to the participating agencies.

A test facility has been built in the department for assessing the pollution potential and the thermal efficiency of residential oil burners.

Studies were conducted in Ottawa on the quality of coking coal that is moved in slurry form in pipelines over long distances. Initial work was carried out on coal transported in water slurries, but a new proposal for developing a slurry system using oil is attracting considerable industrial interest.

Coke-testing facilities at the Ottawa laboratory have been improved through better ventilation, storage and handling, as well as the installation of new equipment. Coking research is being carried out in close co-operation with Canada's steel companies.

Considerable progress has been made in the major pilot-plant investigation being carried out for the Cape Breton Development Corporation. It seeks to find the most economical method for desulphurizing coal from the new Lingan Mine in Nova Scotia, in order to produce a low-sulphur metallurgical-grade coal suitable for converting into coke.

At the Western Regional Laboratory in Edmonton, bench-scale research on flocculation has resulted in a patent application for a process developed by EMR.

Mining engineering. Judged by the number of underground mines (excluding coal mines) producing over 150,000 tons per year, Canada is by far the leading mining nation in the Western World, equalling the combined total of similar mines in the United States, Sweden and Australia. Much of the prestige of Canadian mining rests on this nation's method of underground mining. Research in underground mining seeks to improve existing methods and to develop new ones. The Mining Research Centre of the department has also pioneered the development, testing and use of instrumentation for monitoring rock movement and warning of dangerous conditions. Today, a growing number of mining companies, both large and small, use similar instrumentation and benefit from this research.

The only mining method, however, that promises any short-run defence against the converging pressures of foreign competition, lower domestic grades, and the growing costs of labor and environmental safeguards is the open-pit method. In Canada, over 70 per cent of mine production already comes from open-pit mines, requiring the movement of more than 300 million tons of ore and an equal amount of waste annually.

Open-pit mining costs can be lowered considerably if slope angles can be reduced safely. Consequently, EMR's Mines Branch has embarked on a far-reaching effort to achieve this aim, by enlisting, in addition to its own expertise, that of mining companies, universities and consultants. Much of the work is being done by contract. Full-scale trials of artificial supports for slopes are being made in different rock types.

Studies are being done on the effects of current mining on water quality, and on the probability of public hazards.

Systems engineering offers to the mining industry the advantage of safer, more efficient and competitive production. Research in this

field is designed to assist in the introduction of advanced techniques through co-operative projects with mining companies. Present projects concern the development of automatic control systems for mining machines such as raise borers, diamond drills and comminution operations.

A new service to mining and civil engineering companies has been provided in the Tunnelling Office of Canada, a part of the Mines Branch. The office has begun to distribute information on tunnelling, and preliminary discussions are being held on the formation of an International Tunnelling Society.

Conversion of non-metallic minerals. A considerable amount of work in the Mines Branch concerns the conversion of non-metallic minerals into useful products such as ceramics, construction materials, fillers and chemicals. The work also includes the development and modification of methods for determining thermal and dielectric properties of rocks, minerals and ceramics.

Studies on commercial clays and shales from Alberta, Ontario and Quebec were designed to develop the proper plasticity required by modern automatic processing machinery.

A new project was initiated in co-operation with the Department of Communications to develop improved ceramic dielectrics for use in microwave communication devices.

Long-term projects continued on the development of aggregates for concrete and on the improvement of construction materials of mineral origin. Studies are being made on the effect of extreme temperatures on the behavior of concretes made with different aggregates. To obtain information on severe winter conditions, field projects are undertaken in co-operation with the University of Ottawa. Experiments were carried out with micro fillers consisting of non-mineral wastes such as fly ash, calcined shale dust, siliceous precipitator dust and silica flour, which are used as thermal stabilizers. Initial results are encouraging and indicate that these wastes may become valuable constituents of concrete.

Studies were initiated on the feasibility of producing fine and coarse concrete aggregates from gneissic bedrock at the Jenpeg Dam site, Manitoba. Results are encouraging.

Analytical standards. During the year, the Mines Branch has become more active in work designed to establish standard methods of analysis in the mineralogical and metallurgical fields on a national and international basis, and in the selection, preparation and certification of a range of standard reference materials for use in monitoring analytical procedures. In the development of standard analytical methods, the branch participates in the work of such organizations as the International Organization for Standardization, the American Society for Testing and Materials, the U.S. National Bureau of Standards, the National Institute for Metallurgy of South Africa and others. These methods, when developed, form the basis on which international commerce in mineral products is conducted. Standard analytical methods were developed for such materials as iron and steel, manganese, fluorspar, copper-lead-zinc ores, magnesium and aluminum alloys.

The Canadian Standard Reference Materials Project has been established during the past year to make available for sale a range of standard materials which include pure metals, alloys, minerals, rocks, radioactive sources, etc. The work involves the selection, fabrication, homogeneity testing after comminution, bottling, and certification for the desired elements on the basis of the analytical results provided by a large number of participating outside laboratories, after submission to rigid statistical analysis. The availability of these materials and the plans for the extension of the project to include additional materials have been brought to the attention of the Canadian mineralogical, mining and metallurgical companies.

Mine safety. The manufacture and use of explosives in mining have recently experienced great expansion and diversification, due mainly to the introduction of new types of explosives, such as ammonium nitrate-fuel oil and ammonium nitrate-water gel. This has had its effect on the testing work of the Canadian Explosives Research Laboratory.

Some of the new explosives have proven to be free of hazards, and it has become possible to permit their transportation with conventional safeguards. This has saved the mining industry millions of dollars.

The advent of newer blasting agents has required consideration of the release of noxious gases in underground mining. At the request of provincial mine ministers, the department is seeking to determine the nature of noxious gases produced by blasting with the aim of designing better mine-ventilation systems.

Canada is now third in the world in the production and use of explosives, and has an interest in the international standardization of classifications and markings. To this end, EMR

and the Ministry of Transport have applied for membership in the Dangerous Goods Committee of the Economic and Social Council of the United Nations, the focal point for the development of such international standards.

REMOTE SENSING

Remote sensing by satellite. On July 23, 1972, the first of NASA's Earth Resources Technology Satellites, ERTS-1, was launched into a circular, near-polar orbit which provides complete global coverage once every 18 days from 81 degrees north to 81 degrees south. To read out Canadian data, an existing 85-foot parabolic dish antenna system at Prince Albert, Sask., was converted and equipped with appropriate tracking and recording facilities. Since three days after launch, imagery of Canada has been received almost continuously from the satellite's four-band multispectral scanner. A Ground Data Handling Centre which can process both ERTS and certain airborne remotely sensed data was established in Ottawa.

ERTS imagery is produced as both black and white and color composite images each encompassing an area 185 km by 185 km. There are usually four orbits and 60 to 65 scenes a day over Canada; the entire country can be covered in approximately 1,500 images. Users of ERTS imagery can order copies through a computer-based inventory and ordering system. In all, 308 standing orders were received in 1972-73, ranging in coverage requested from a small section of one province to the whole country. The reproduction and distribution of ERTS imagery is handled by the National Air Photo Library, whose Reproduction Centre is located in the same building as the Canada Centre for Remote Sensing.

In addition, ERTS-1 has the ability to retransmit data which have been collected by remote data-collection platforms, and there are currently 14 of these in Canada, deployed by user agencies in various disciplines and being operated on an experimental basis.

Airborne remote sensing. In 1972-73, the Canada Centre for Remote Sensing expanded its activities in airborne remote sensing with the use of two more aircraft. The fleet is now composed of four: two DC-3's, a Falcon Fanjet and one CF-100. Three of these were flying user-requested projects, and one of the DC-3's was reserved for project back-up and as an experimental test-bed for new systems. As in previous years, the Canadian Forces Airborne Sensing Unit performed all the actual flying and aircraft maintenance.

In all, 35,346 sensor line-miles were flown in 116 different projects. This, however, was only about 60 per cent of the planned mileage, due mainly to unusually poor flying weather and severe difficulties with equipment. By far the largest consumers of airborne remote sensing this year were agencies of the Department of the Environment and a number of Canadian universities.

Development began this year on a fully automatic Airborne Data Acquisition System (ADAS) for one of the aircraft. This is a computer-controlled system for centralizing and annotating all of the data gathered from a multitude of sensors aboard the aircraft, and will be used primarily for special programs where accuracy of integrated sensor systems is essential. The ADAS system will be integrated with an inertial-guidance-navigation system for the provision of real-time path-recovery information.

Applications of remote sensing. The Canada Centre for Remote Sensing is committed to developing remote sensing to its effective potential, and toward that end it began a major staffing program in the Applications Division. This has included environmental scientists for applications development, people with interpretive skills and a knowledge of remote-sensing techniques; and research scientists to work on methodology, with complementary skills in the use of physical and mathematical techniques to solve problems and provide numeric solutions by computer techniques.

By year's end, several state-of-the-art pieces of equipment had been acquired to aid these scientists in their work.

While the bulk of data interpretation rests with user agencies, the centre has identified a number of investigative projects which are technologically attractive, in as much as they promise high benefit-to-cost returns and offer an opportunity to develop some of those techniques of remote sensing which could have application to several different disciplines in the environmental and earth-resources fields. The projects will be undertaken as joint efforts with the user agencies concerned, and are expected to yield good demonstrations of the practical applications of remote sensing.

An example of the centre's experimental efforts which may well end in operational application is an investigation of a controlled oil spill in the Bahamas. The project, undertaken in co-operation with the Bahamian Government and the Canadian Department of the Environment, took place in February 1973, and the results

will be used as an aid to determining suitable locations for supertanker ports in the islands.

Another program initiated this year is a co-operative effort in aerial hydrography, undertaken in conjunction with the Marine Sciences Branch of the Department of the Environment. It involves water-depth determination using an aircraft, particularly in coastal and shallow waters where currently used water-based techniques are time-consuming, difficult, and at times extremely dangerous. One of the aircraft has been fitted out with an extremely accurate inertial navigation system to allow precise determination of aircraft position, and as imagery is gathered over the next 18 months it will be largely analyzed by the third participant, the University of New Brunswick.

Under the federal government's winter works program, the centre was able to temporarily expand its applications efforts through the establishment of regional winter works offices across the country. Each office was staffed by interpreters experienced in one or more of the major user disciplines who could assist users in their area in obtaining remote-sensing imagery and services to fill their requirements. These local offices, while not permanent, have provided an important educational function in these developmental stages of remote sensing in Canada.

Sensor development. Sensor development, now entering its fourth year, has reached the point where many of the projects are attracting funding from user agencies. Several sensors were field-tested this year, and two new projects initiated.

HISS, an entirely new principle for measuring the thickness of sea ice, is being developed by the Department of Electrical Engineering at the University of Toronto. This system, which uses the concept of microwave holography, was test-flown in the Canadian Arctic in May 1972. Promising results were produced from the initial data, and the completion of the rest of the system hardware is expected to reduce the time to operational status.

At York University, a laser ranging device (LIDAR) has been further improved and has been used extensively for measuring atmospheric constituents over Toronto. This work is now receiving funding support from the Atmospheric Environment Service, and a similar device for use on shipboard to profile water pollution is being funded at York by the Canada Centre for Inland Waters in Burlington.

Two other novel remote-sensing devices from York University were flight-tested during the past summer. One is a multiplex filter photometer which proved successful in measuring chlorophyl concentration in lakes from the air. The other, an Image Intensifier Spectrometer, was flown in March, and successfully detected a test dye introduced into Lake Ontario in extremely low concentrations. Further development on both of these devices continues.

Also in the field of water-pollution studies is a laser fluorosensor at the University of Toronto's Institute for Aerospace Studies. The device was thoroughly field-tested during the summer, and demonstrated a very promising capability. It is being adapted at the centre to fly in the experimental DC-3 in the summer of 1973 to monitor oil pollution on water, and to measure water depth.

Barringer Research has built a carbon-monoxide detector which is expected to have application in, for example, the detection of incipient forest fires by monitoring the associated carbon monoxide.

In addition to the above, the Canada Centre for Remote Sensing has pursued the development through outside contractors of several other novel remote-sensing devices. These include advanced work in the field of infrared photography (McMaster University), and an image-dissection camera (SPAR Aerospace). The centre's sensor development program continues to contribute to the state of the art in remote sensing.

ENVIRONMENTAL CONCERNS

In the energy field. Increasing attention is being given to the environmental factor in policy recommendations relative to oil and gas production, transportation, processing and use. The $20-million budget of the Task Force on Northern Oil Development for research on northern pipelines is in large part directed to the determination of the ecological characteristics of the proposed route and to the design of construction and operation procedures that would protect the terrain and the wildlife and fish resources of the north.

Methods to reduce atmospheric pollution from automobile operation and industrial plants are under study to determine their effectiveness and costs to the economy. One of the most important challenges to be faced in controlling the environmental effects of oil-resource development will arise with the opening up of the Athabasca oil sands on a large scale. The production and use of oil and gas and their products possibly raise more environmental concerns that any other activity in the modern industrial economy; hence the need for a high

priority to environmental matters in oil and gas policy work.

Resource administration by EMR's Energy Sector includes ensuring minimum environmental risk to the marine environment, with full regard for the safety of human life and the living resources of the sea. Canada's safety requirements for offshore drilling are among the world's most stringent, and are backed up by a comprehensive program of enforcement based on regular inspection of operations. The Oil and Gas Production and Conservation Act provides full authority to shut down operations in the interests of safety or pollution prevention, to prohibit their resumption until adequate remedial steps have been taken, and indeed to take over management and control of an operation at the operator's cost if satisfactory steps are not being taken to remedy the situation.

Close working relations are maintained with the Department of the Environment to ensure adequate and timely agreement to expand knowledge and to develop standards relating to environmental effects of electrical-energy production.

The department is represented on the Lake Winnipeg, Churchill and Nelson Rivers Study Board and on the Yukon Water Board and the Northwest Territories Water Board established under the provision of the Northern Inland Waters Act, to license water use and maintain water quality in both Territories.

Geological studies. The need to use and exploit the environment often leads to conflict, and a rational management requires a broad knowledge base to which the studies of modern geological processes contribute. The Geological Survey has carried out a wide variety of studies under this general objective. Some of them deal with the provision of use-hazard information on the behavior of earth and rock materials under specific conditions, especially in the Arctic regions where the extreme sensitivity of the terrain to man-made disturbance has become a matter of public concern. Selected sites on Melville Island were chosen to study thaw depths and gullying under mechanical disturbance. Investigations were also made on Ellesmere Island on the effects of construction and vehicle operation. In more southerly regions with greater population pressure, investigations were concerned with pollution and land restoration of coal-mining areas in British Columbia, with landslips in the Ottawa-Hull region and with the future land use of the region surrounding the new Montreal International Airport.

In the Mackenzie Valley, a number of projects were carried out as part of the department's contribution to the Environmental Social Program of the Task Force on Northern Oil Development. Some of these dealt with broad conceptual aspects and land classification especially related to terrain sensitivity; others involved studies of permafrost growth, erosion under permafrost conditions and such practical considerations as the instability of slopes and riverbanks which present an immediate threat to any nearby facilities such as roads, pipelines or structures.

Shallow seismic research was carried out in the Mackenzie River valley and delta areas for the investigation of the seismic properties of earth materials in the permafrost environment and in the detection of massive ice lensing at depth. Marine refraction profiling was conducted in the delta and the Beaufort Sea to map the occurrence of sub-seabottom permafrost.

The need for environmental concern is no longer limited to the land as we approach an era in which it is likely that extensive development will be undertaken in the coastal zone and the offshore environment. The impact must be predicted and any changes in the environment due to such development must be monitored, including the development of a capability to deal with contingencies such as oil spills, discharge of industrial effluents and the collapse of man-made structures. The Geological Survey, through its Atlantic Geoscience Centre, has already under way a number of projects such as those concerned with suspended sediments in the Bay of Fundy and the evaluation of industrial outfall, and with methods of silicate analysis of suspended and deposited sediments. Studies were also made on the distribution of various marine organisms, notably foraminifera, which provide sensitive indicators of changing conditions in the marine environment, man-induced or natural.

Safety and pollution abatement in mining and metallurgy. It is becoming increasingly apparent that if the fullest benefit is to be derived from rapid advances in mining technology achieved in recent years, research concerning health and safety must keep pace with the development of production. The department has undertaken research in several principal areas: dust and radiation, noise, dangerous gases such as methane, diesel exhausts and spontaneous combustion.

Progress has been made in determining dust levels and radioactive daughter products of radon in uranium mines. Initial studies were completed concerning the effect of noise in mining, methods of combatting its harmful effects, and Canadian and U.S. legislation to control it. Field work has started on gas emission in coal mines.

There is growing evidence that modern methods of mining coal increase the risk of spontaneous combustion, which could hinder the development of the coal industry in Canada. Results from studies conducted so far are preliminary.

The apparatus for testing diesel engines in the Canadian Explosive Atmospheres Laboratory has been completed. Four types of machines have been certified by this new service for use in coal mines in Alberta and British Columbia. The testing is paralleled by research on the technology of diesel-engine use under ground.

Both mining and metallurgical operations use large quantities of water, and in past years it was the general practice to draw the water from the lakes and rivers so abundant in Canada, and to return the water to the source after use. However, such water is often contaminated with various chemicals, and restrictions have recently been placed on its discharge.

The simplest means of preventing the discharge of contaminated water is recycling, but this is often not wholly practicable. The Mines Branch of the department is studying ways and means of extracting or neutralizing harmful chemicals contained in mine effluents.

Re-vegetation is generally recognized as the most practical means of stabilizing the surface of mine-waste dumps. Not only does it prevent erosion by wind and water, reducing the polluting effects of airborne dust and seepage, but it is also more pleasing to the eye than physical or chemical methods. Research is being conducted on the survival of plants on highly siliceous and acid mine tailings.

Other research aims at reducing air pollution in electric smelting and iron-making, and at the prevention of water pollution by coal fines, as at the coal-loading terminal in Vancouver.

Conversion of waste. Research is continuing into possibilities of converting waste material from mining and processing it into useful products.

For example, it was found that a mixture of asbestos tailings with sand gave a rock-wool insulation of good quality. Some other attempts to turn waste into commercially attractive materials proved interesting but inconclusive. A comprehensive program was started in 1972 for reducing mine and mill tailings and reducing environmental degradation. Results indicated that tailings from base-metal mines, because of high contents of impurities and/or remote locations are of little interest, but other tailings, such as those from gold mines, have higher non-metallic contents and may serve as raw material for local production of such useful products as sand-lime brick.

Earthquake hazard. The Earth Physics Branch maintains and operates 22 standard seismograph stations in the Canadian Seismic Network. In addition, 11 regional stations were operated in co-operation with other agencies.

Preliminary locations and magnitudes of about 100 of the larger Canadian earthquakes were determined, and the final results for 1967 were sent to press -- about 400 Canadian earthquakes were detected, located and their focal parameters determined. The detailed study of earthquakes in western Canada during 1968 was completed. Studies were conducted in the field and in the extensive archives of the department for reports covering the seismicity of the potential pipeline corridors in the Yukon and Mackenzie Valley, and of the St. Lawrence Valley near Quebec City. Numerous requests for information were answered.

The fruitful co-operation with the United Kingdom, the United States, Sweden, Norway, and Japan in the field of nuclear detection and identification was continued by means of reciprocal visits and joint studies resulting in the publication of scientific papers. As well, individual and co-operative studies by Canadian scientists resulted in the publication of several important papers. Preliminary tests on tape-recorded data indicate that the automatic on-line digital processing system scheduled to commence operation at the Yellowknife array in 1973-74 will achieve a very good detection level, thus contributing substantially to the world-wide monitoring of seismic events. The Canadian scientific effort in these fields continues to play a leading role in the delineation of the problems (and their possible solutions) in the continuing search for a means of policing a nuclear-test ban.

ICE STUDIES

The Arctic Ice Dynamics Joint Experiment (AIDJEX) is a co-operative, multi-discipline investigation of the dynamic behavior of ice, and of the transfer of kinetic and thermal energy between the atmosphere and the ocean through a complete or partial ice cover. The information to be obtained from it will help in forecasting the movement and variations in behavior of sea ice, in understanding climatic trends and in planning or designing structures and transport routes connected

with resource development in or near the Arctic Ocean. It is an international undertaking, with participating agencies from Canada, the United States and Japan.

Major AIDJEX field activities in 1972 consisted of a pilot study to develop instruments and techniques for air, water and ice measurements and to test certain scientific assumptions in preparation for a major field season in 1975. The pilot study was supported by the department's Polar Continental Shelf Project in the Beaufort Sea.

The first edition of the Sea-Ice Atlas based on data collected from 1961 through 1968 will be published shortly.

RESOURCE ADMINISTRATION AND REGULATION

The department is responsible for federal interests in mineral resources off Canada's east and west coasts and in the Hudson Bay and Hudson Strait regions, as well as those federally owned mineral rights within the provinces that become available for development.

During the year, two discoveries were announced as the result of exploratory drilling on the Scotian Shelf, in addition to the Sable Island discovery of 1971. The first of these finds, Primrose, 30 miles east of Sable Island, was a gas and oil discovery; the second, Thebaud, 6 miles southwest of Sable Island, involved gas and condensate. Interesting shows of gas were encountered in a third well on the Scotian Shelf, and shows of oil were found in two wells on the Grand Banks. The level of industry activity in the east coast offshore continued to increase, due partly to these favorable indications and partly to the pressures of the work commitments of the oil and gas exploration permits.

The department issues and administers various types of terminable offshore mineral grants, taking into account the unique conditions of the offshore environment. These grants, varying from non-exclusive licences through exploration permits to exclusive production leases, are issued and administered under the Canada Oil and Gas Land Regulations. These regulations are currently under extensive review, and comprehensive revisions are expected to be announced in the near future.

Pending revision of the regulations, the issuance of Canada Oil and Gas Permits was suspended on March 21, 1972; no permits were issued during the fiscal year 1972-73. The number of offshore permits administered by EMR as of March 31, 1973, was 4,779, covering 345.3 million acres, in the following areas (per cent reduction of acreage during the year is shown in brackets):

East Coast--3914 permits--290,805,533 acres(-8%)
West Coast--233 permits--16,043,850 acres(-1.5%)
Hudson Bay - Hudson Strait--632 permits - 38,467,969 acres(-45%)

The reduction in offshore holdings during the year is part of the normal evolution, of federal oil and gas permits, as favorable areas are consolidated. Total revenues received from offshore permits during 1972-73 amounted to $680,769, up 25 per cent from the previous year.

The potential for offshore mineral resources other than oil and gas is also promising. However, in Canada as in other parts of the world offshore mining lags behind the offshore oil and gas industry both in the discovery of commercial offshore mineral deposits and in the technology of their recovery. No offshore claims were recorded during the fiscal year. In effect on March 31, 1973 were East coast 54, West coast 28, Hudson Bay 38 - a total of 120.

In the provinces, 57 oil and gas leases were issued as the result of two sales by public tender, bringing the total of federal oil and gas leases to 282, as follows: Alberta 160, Saskatchewan 102, Manitoba 17 and Ontario 3. As of March 31, 1973, distribution of productive oil and/or gas leases was: Alberta 35, Saskatchewan 22, Manitoba 9 and Ontario 1, making a total of 67. In addition, one potash lease is under production in Saskatchewan, and two leases for minerals other than oil and gas are held in Ontario. Revenues during 1972-73 from federal mineral leases in the provinces amounted to $399,077, most of which was derived from oil and gas.

This work of the Resource Management and Conservation Branch comprises not only the regulation and supervision of increasing offshore exploratory activity, but also the detailed evaluation of the structural and reservoir conditions and hydrocarbon distribution within the various prospects themselves, as well as the economics and logistics of development and transportation systems. The thorough and continuing assessment of the potential of offshore hydrocarbon prospects forms a basis for federal policy on management of mineral rights, operational and environmental requirements, federal-provincial relations, and future plans for pipelines and storage facilities.

Some 150 separate offshore exploratory programs were undertaken by industry in the search for offshore oil and gas during 1972, including 21 drilling projects off the east coast. The petroleum industry spent some $66 million exploring for oil and gas. Of this total, $16 million was spent on geophysical and geological surveys and $50 million for exploratory and assessment drilling. Direct expenditures by industry in Canada's offshore to the end of 1972 (excluding the high Arctic offshore) reached $237 million: $92 million for geophysical and geological surveys and $145 million for drilling. Almost $200 million of this was spent off the east coast.

Offshore programs are reviewed and supervised constantly to ensure adherence to federal requirements designed to minimize the possibility of accidents, prevent pollution of the marine environment, prevent waste of resources and avoid conflict with other users of the offshore.

To the end of March 1973, 78 wells had been drilled in the Canadian offshore.

Departmental officials attended meetings in Geneva and New York of the 90-member United Nations Committee on the Peaceful Uses of the Seabed and Ocean Floor beyond the Limits of National Jurisdiction. At issue, among other matters, is the definition of the outer limit of national jurisdiction and the nature of the international regime and machinery required to manage the seabed resources of the area beyond. Much is at stake for Canada, both in the determination of the outer limits of national jurisdiction and in the efficacy of the regime and machinery to govern the international area beyond.

The department also participated during the year in negotiations with France and Denmark with respect to the delimitation of offshore boundaries of jurisdiction over seabed resources in the St. Pierre Bank and the Baffin Bay/Davis Strait regions, respectively.

SERVICES AND STATUTORY RESPONSIBILITIES

Legal surveys in federal lands. Whereas provincial governments have jurisdiction over legal surveys in their territories, the federal government, through EMR's Legal Surveys Division, carries out and supervises such surveys in federal lands within provinces (i.e., national parks and Indian reserves), and in the Yukon and Northwest Territories. It also undertakes certain other tasks, such as the demarcation of interprovincial boundaries, the certification of Dominion Land Surveyors, and the control of oil and gas surveys made pursuant to the Canada Oil and Gas Land Regulations both in the northern territories and on Canada's continental shelves.

During the fiscal year, 19 field parties completed 89 separate survey projects: on Indian reserves in all provinces except Newfoundland and Prince Edward Island, and 6 in the Northwest Territories. To complete as many as possible of the projects required for federal government departments, 196 were done under contract.

Three federally appointed commissions, of which the Surveyor General of Canada Lands is a member, worked on the survey and maintenance of provincial boundaries. The Manitoba-Saskatchewan Boundary Commission continued to have work undertaken on the returns of the boundary survey. On the British Columbia-Yukon Territory boundary, the results of a previous spraying operation were inspected; it was found that, although satisfactory in part, the spray did not completely kill black spruce. The Saskatchewan-Northwest Territories boundary vista was completely cleared during the winter of 1972-73.

Aeronautical charts and publications. Discharging its obligations concerning the regulation, safety and development of Canadian civil and military aviation, the department produced 54 aeronautical chart series and flight-information publications in 1972-73 according to internationally accepted schedules and standards.

A new publication, VFR Supplement, was produced to provide the aeronautical community with summarized land aerodrome and associated chart data up to the latitude of 60°N. Information north of 60° will be supplied by the Northern Supplement scheduled for publication next year. Both of these documents will have 84-day revision cycles.

Conversion of the World Aeronautical Chart series (scale 1:1,000,000) to the large-sheet back-to-back printing format was completed, while development of charts for short take-off and landing (STOL) flights between Montreal and Ottawa continues to accelerate, along with certain military aeronautical requirements.

International Boundary Commission. Under terms of a treaty signed in 1925 between Canada and the United States, a permanent commission was established with responsibility for the effective definition and marking of the boundary between the two countries. The commission was also responsible for the resurvey of any part of the boundary, if and when deemed necessary. The Canadian section of the commission is, for operational purposes, incorporated in the department's Surveys and Mapping Branch.

Canadian field parties operated in three areas during the year. On the Quebec 45th-parallel boundary a geodimeter traverse was continued between boundary monuments to update existing survey data, with ties being made to the associated control triangulation. The boundary traverse determined new positions for 40 boundary monuments, with observations being made at 14 triangulation stations to provide control for 55 miles of traverse. In the course of this work 76 monuments were inspected and three repaired, one was relocated, and two control stations were re-established.

In the west, the Canadian section operated a vista-maintenance party along the British Columbia-Washington boundary. Thirty miles of 20-foot vista was cleared of undesirable growth, and 24 miles was treated with herbicides to deter further growth. A three-mile stretch of boundary vista was groomed by bulldozer and seeded with grass to assess grooming and mowing as an alternate approach to vista maintenance in settled areas. The commission field party, while operating along the 49th-parallel boundary, inspected 53 monuments and repaired 30. Later in the season operations were carried out along the British Columbia-Alaska boundary.

Four miles of 20-foot vista at the head of Portland Canal was cleared of heavy growth and six monuments and three triangulation stations were recovered in an assessment of the need for future work in that area.

Explosives administration. The Explosives Division is responsible for regulating all factories that produce commercial blasting explosives, military explosives, blasting accessories, gunpowder, smokeless powder and percussion primers, ammunition, fireworks and other pyrotechnics, and for the quality and safety of the products. This responsibility also extends to the road transportation of these items and to their storage and importation. Control is exercised by a system of licences, permits and sales records supported by inspections by members of the division and by the Royal Canadian Mounted Police. All such licences and permits are issued from the Ottawa Office.

The number of factories licensed to manufacture explosives increased to 60 by March 31, 1973; some 370,000,000 pounds of commercial blasting explosives was produced. The production of fireworks, ammunition, blasting accessories and military explosives also increased over the same period. No existing factories ceased operations, and the number of licences issued for the storage of blasting explosives increased to 1,300.

As a result of amended regulations under the Canada Explosives Act, all display fireworks must now be fired under the supervision of a qualified person. Accordingly, the division undertook to provide free courses to qualify candidates as "Fireworks Supervisors." The pilot course was held in Toronto on March 25, 1973, and similar courses will be conducted across Canada. Successful graduates receive a Fireworks Supervisor Card which is registered with the division.

Bill C-7, an act to amend the Explosives Act, which was introduced in the House of Commons in February 1972, was allowed to lapse at second reading. However, this Bill which will establish more effective control over the sale, purchase, possession and security of explosives will again be recommended by the division at a later date.

Members of the Explosives Division promote safety measures and regularly meet with members of industry, federal and provincial government agencies, municipal authorities and other groups involved in the handling of explosives. The division has available for distribution safety literature on the storage, handling and transportation of explosives.

RESEARCH AGREEMENTS

The underlying purpose of the department's Research Agreements is to fund extramural research and development projects that are directly related to the department's mission. Canadian research organizations that are not directly managed by the federal government and that undertake research in the natural, physical and social sciences and engineering are eligible to apply on behalf of individual investigators in their employ.

The intention is to bring many kinds of expertise to bear on the problems of national policy, to apply a multidisciplinary competence to the development of advice to the government and information for the community at large. The branches of EMR, with their disciplinary orientation, are responsible for assessing the proposals which relate to their own objectives and activities, and for monitoring the investigations throughout the life of the agreement.

For the second year of operation, the level of funding was increased by $289,000 providing a total of $865,000. The committee received 303 applications, requesting a total of $3,604,249; 119 Research Agreements were recommended: 111 to university projects, 6 to provincial science councils, 1 to the Royal Ontario Museum, and 1 to industry.

Typical research projects included:

- the social impact of alternative energy-transportation modes in the Mackenzie River valley;
- federal-provincial management of oil and gas resources;
- government expenditures for declining industries;
- development of guidelines for safe and efficient mining of potash in Canada;
- chemistry of pyrite in ore tailings and coal;
- ferro-manganese exploitation of the ocean floor;
- mineral exploration research in western Canada;
- metallogeny of central Newfoundland;
- shoreline erosion on the Great Lakes;
- seismicity in the Quebec City region;
- a study of nationalization of a Canadian company, and the implications for Canadian mineral resources policy.

Department of
ENERGY, MINES AND RESOURCES

ANNUAL REPORT 1973-74

Energy, Mines and Resources Canada

Donald S. Macdonald, Minister
T. K. Shoyama, Deputy Minister

Left: Grading Mackenzie Highway, near Fort Simpson, Northwest Territories. Members of EMR's Geological Survey of Canada are acting as advisers on this important construction project.

Center: Member of EMR's Earth Physics Branch uses portable core drill to obtain rock sample for paleomagnetic research. Takiyuak Lake, Northwest Territories.

Right: Two suns seem to be shining on this camp of the Polar Continental Shelf Project. One (left) is what is known as a "sun dog," a reflection of the sun.

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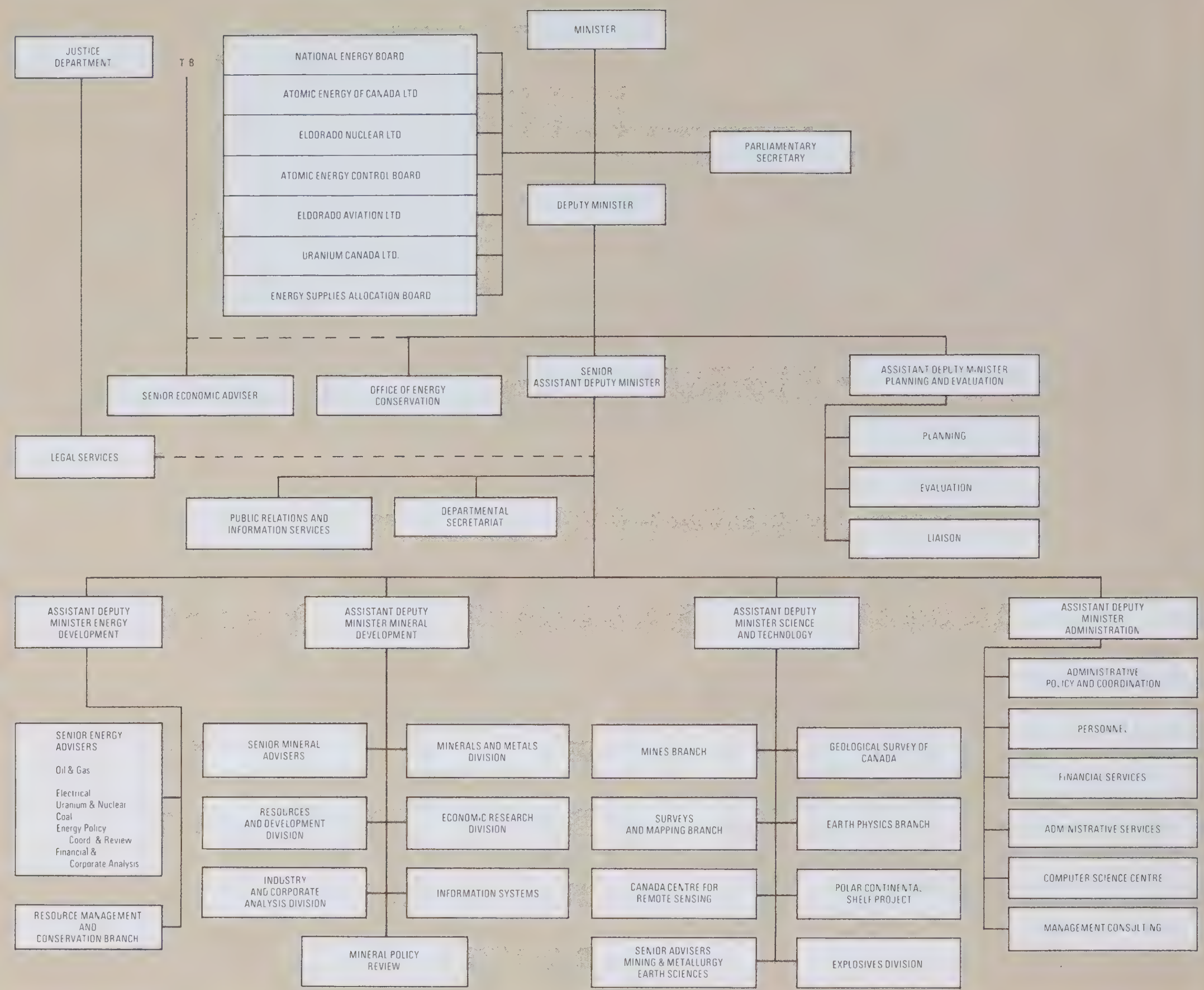
Department of Energy, Mines and Resources



INTRODUCTION

A single economic development with far-reaching social and political implications dominated the concerns of the Department of Energy, Mines and Resources in the fiscal year 1973–74. This was the crisis in the supply of petroleum, which broke upon the world, and Canada, in the fall of 1973. EMR, being charged with collecting and analyzing information on the energy situation in Canada and abroad, and with providing policy advice on energy management to Cabinet, found itself in the public limelight throughout the year.

This large measure of public attention was due not only to the crisis itself but also the publication, in June 1973, of the long-awaited Phase I of "An Energy Policy for Canada." Phase I was the energy analysis which was intended to lead to Phase II—an assemblage of concrete policies to be worked out in consultation with all the interested parties in the country. In the meantime, a number of the postulates in Phase I have been overtaken by the consequences of the fuel crisis, and various emergency measures had to be devised to ward off the most immediate and most serious shortages and/or price increases in gasoline and heating oil. Thus, for example, the

EMR budget was suddenly inflated to almost triple its normal size by the inclusion of $157 million for payment of oil subsidies.

More detail on this and other activities of EMR's Energy Sector will be found in the pages that follow.

Long-term policy considerations were also the uppermost concern of the Mineral Development Sector, which bears a responsibility similar to that of the Energy Sector in respect of all of Canada's metals and industrial minerals, their processing and factors governing their exportation and importation.

Early in the fiscal year the ten provincial mines ministers and the Minister of Energy, Mines and Resources announced objectives for a national mineral policy, incorporating many of the recommendations of departmental experts. Continuing intensive discussions among Ottawa, the provinces and private companies have focused on assigning priorities to the objectives, with emphasis to be placed on increasing mineral-based manufacturing and mineral processing in this country. Most mineral commodities increase their value manifold, and generate a large range of economic benefits, if processed to manufactured products in the country of origin. On the other hand, most nations now importing Canadian minerals have set up tariff and other barriers to manufactured products. An effective mineral policy must seek to increase the one factor while reducing the other.

The sudden attention forced upon energy and mineral commodities has not diminished the relative importance of the work of EMR's Science and Technology Sector, whose staff engages mainly in the accumulation, interpretation and diffusion of geological, geophysical, metallurgical, mining, topographical, remote sensing and other information. On the contrary: the crisis in the commodity field cannot be solved without the contributions of the sciences and technologies indicated above. For example, if natural gas were to be discovered in large quantities in the Arctic, a pipeline to Ontario and Quebec markets could be built successfully only if exact, reliable information were available on the terrain to be traversed, including such factors as permafrost, topography, sea-ice patterns, etc.: such information is now being collected and analyzed by the Canada Centre for Remote Sensing, the Surveys and Mapping Branch, the Geological Survey of Canada, the Earth Physics Branch, and the agencies supported by the Polar Continental Shelf Project—all parts of EMR. If a petroleum and/or gas discovery occurs, this will be due in large measure to the basic surveys carried out over many years by the Geological Survey and the Earth Physics Branch. Furthermore, only special types of pipe, manufactured from special steels and welded by special methods, will stand up to the rigors of the Arctic. Research on such metallurgical problems is being carried out in EMR's Mines Branch. The larger questions of financing a pipeline and of marketing its throughput are being considered and advised on by the Energy Sector.

This is just one example of the intertwining of the activities engaged in by the various components that make up EMR. Such multi-disciplinary approaches are more and more common in EMR—and this itself is one of the most significant new developments in the department's history.

An important new data-base system was inaugurated by the Surveys and Mapping Branch, which uses a computer bank of mapping information. The information, which can rapidly be processed into a variety of map types, is accessible to all interested agencies.

Most of the field activities of the Geological Survey of Canada now concern the Canadian North, where geological rock and sediment types indicate a potential for mineral wealth that is as great as the known mineral resources of more southerly parts of the Canadian Shield and the Prairies. Also, the growing impact of man's industrial activity in the Arctic has prompted a large range of terrain studies aimed at preventing unnecessary damage both to the environment and to northern societies.

Broad human concerns were also in evidence in the research of the Mines Branch, much of which was directed toward finding more effective and less polluting ways of combustion and ore treatment, or of finding new uses for the large heaps of waste material that are often an undesirable feature at mine sites.

Improvements were made at the Earth Physics Branch's seismic array at Yellowknife, which allow "seismic events" (earthquakes or underground nuclear explosions) to be computer-processed as they happen. A telephone connection between computers in Ottawa and the Yellowknife equipment, to be established soon, will make the processed information available in Ottawa within 24 hours.

The fiscal year 1973–74 was the first full year of operation of the Earth Resources Technology Satellite (ERTS), imagery from which is received, processed and distributed by EMR's Canada Centre for Remote Sensing and the National Air Photo Library. A novel and potentially significant experiment in remote sensing was the transmission of imagery of Arctic sea ice to ships plying the Arctic sea lanes.

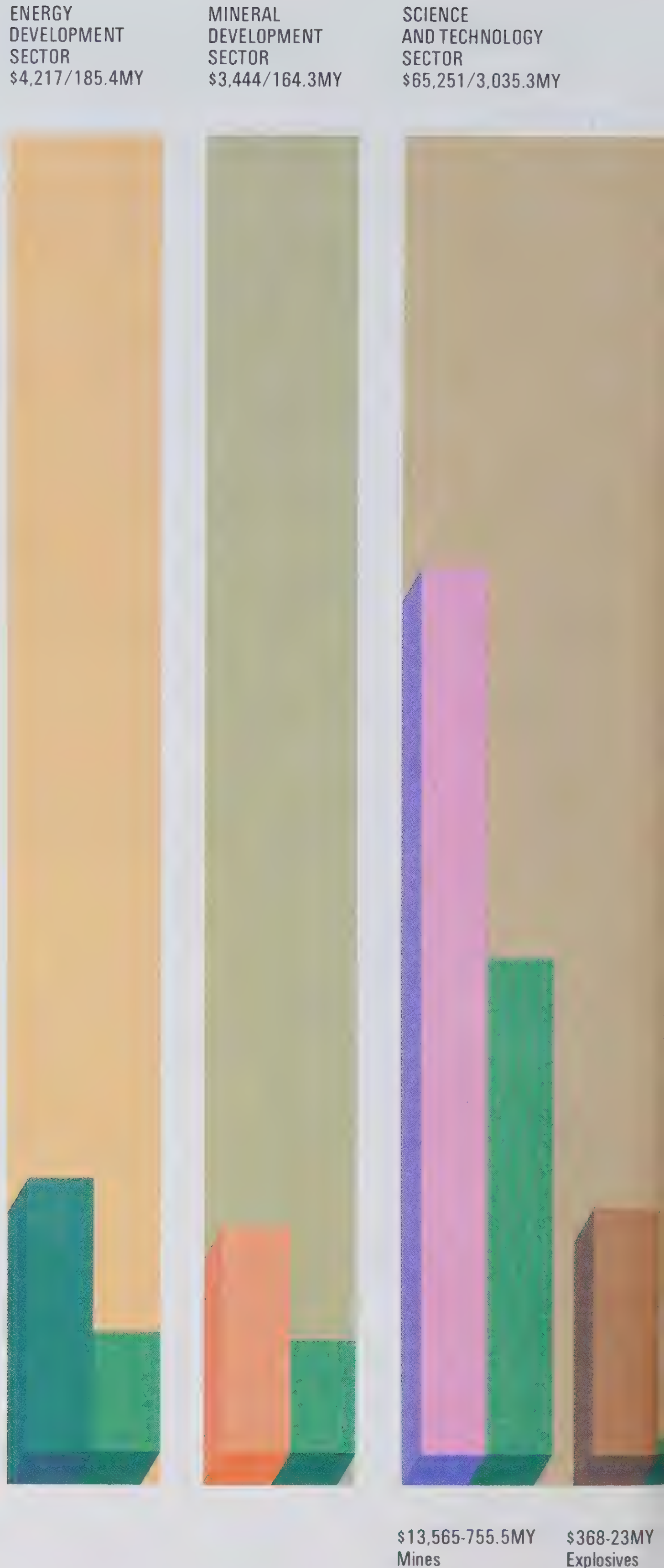
The Polar Continental Shelf Project again supported a wide range of scientific and technical researches in the Canadian Arctic. A number of appointments were made at the senior-management level of EMR, as follows: G. M. MacNabb, former Assistant Deputy Minister, Energy Development, was named Senior Assistant Deputy Minister; J. T. Lyon was named Legal Advisor to the department; John Convey, former Director of the Mines Branch, was named Senior Advisor Mining and Metallurgy; W. H. Hopper was named Assistant Deputy Minister, Energy Development; and A. T. Prince was named Assistant Deputy Minister, Planning and Evaluation.

Several branches of the department were given new directors; appointments are noted in the relevant sections of the report.

Details about some of the more significant and interesting projects undertaken during the past year by EMR's components will be found in the following pages. It should be noted here that in view of the tremendous number and variety of projects no attempt was made at comprehensive coverage. Readers interested in detailed, professional information are urged to apply directly to the sectors or branches concerned, all of which publish professional reports of their activities.

Department of Energy, Mines and Resources

1973-1974 Estimates in thousands of dollars and man years.
Total for department: $237,042*
3,856 man years (MY)



*Oil Subsidies $157,359

ADMINISTRATION
$6,771/471MY
,387-794MY
logical
vey
anada
$17,231-1,136.3MY
Surveys
and Mapping
$5,016-184.5MY
Earth
Physics
$2,951-33MY
Polar Continental
Shelf
$6,552-101MY
Remote
Sensing
$181-8MY
Assistant
Deputy
Minister

ENERGY DEVELOPMENT SECTOR

June 28, 1973, saw the culmination of many months of hard work by the Energy Development Sector when the Minister tabled Volumes I and II of Phase I of "An Energy Policy for Canada" in the House of Commons.

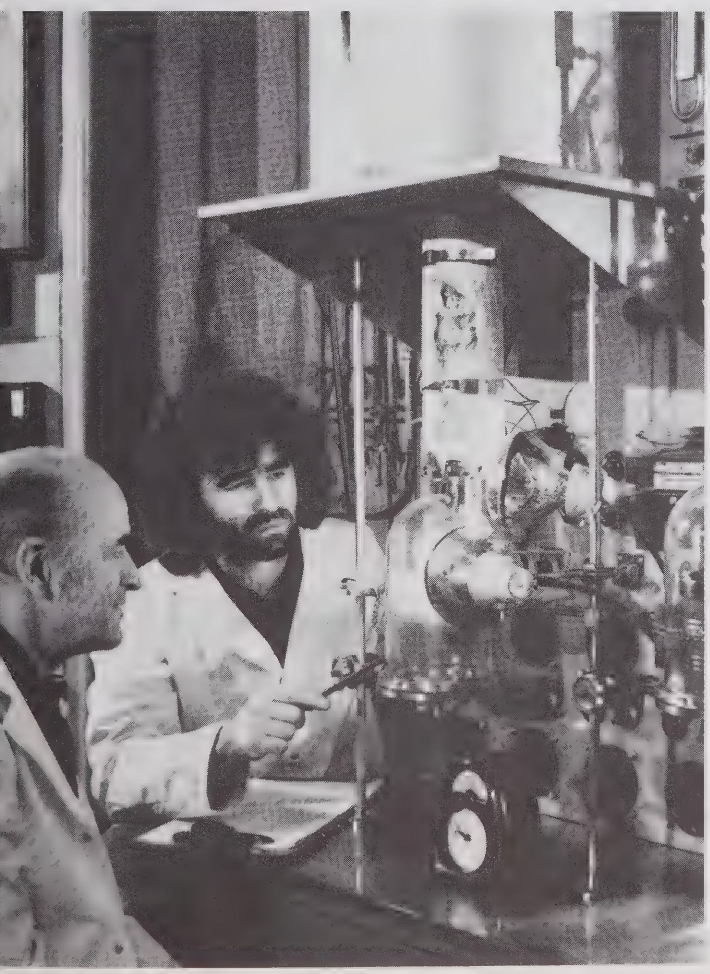
The report covered all aspects of the energy situation in Canada and laid out various options that could be carried out in the future. The analysis forms the framework for future policy development. It is also being used as a vehicle to obtain views of the public at large as well as industry, provincial governments and special interest groups. Extensive consultations had been planned at that time so that, as the Minister said in the foreword to Volume I, ". . . following those consultations the Government of Canada will then reach the second phase of the approach to the energy problems of deciding how, and with what instruments, our existing policies should be altered."

Widespread distribution of the report had been planned, and to enlarge this distribution Public Relations and Information Services produced a booklet called "Energy and Our Way Of Life" based on the analysis, for use in schools. Teachers and students received 210,000 copies through a Canadian high-school magazine and a further 600,000 were requested by teachers for use in school classrooms.

The workload of the Energy Sector did not, however, ease with the publication of the energy analysis. Lights burned in sector offices into the early hours of the morning in the fall of 1973 as a result of events in the Middle East.

The dramatic *rise in the cost of oil* from OPEC (Organization of Petroleum Exporting Countries), the cutback of production in the Middle East, and the embargo of oil shipments to the United States did have an effect on Canada. It seemed in the fall that there could be serious shortages of home heating fuel in eastern Canada during the winter. However, steps taken by the oil companies and the federal government, plus the help of a mild winter, eased the situation.

The price of Canadian oil had also been rising during 1973 and, to ease the financial burden on Canadian consumers, the government on September 4, 1973, requested the oil companies to impose a voluntary freeze on price increases. While this was in effect the oil companies were permitted to pass on two international price increases, effective November 1 and December 1, for oil used in the region east of the Ottawa Valley line, which depends on imported oil. West of that line the price remained at September levels well into 1974.



Mines Branch fuel experts determine the "pitch" content of a sample of oil produced from Athabasca oil and bitumen. The "pitch" is the non-saleable portion of the refined bitumen.

So that Canadian oil would not be sold in the United States at less than the world price, a tax was placed on all exports of crude oil from Canada. Also, extension of pipeline facilities from Sarnia to the Montreal area was planned to provide additional security against international disruption of supply. Hearings were to be conducted before the National Energy Board to determine feasibility of the plan before final approval. This would be part of a longer-term plan for a coast-to-coast oil-pipeline system as announced on January 16, 1974.

At the time when it was expected that there might be severe shortages of oil during the winter the government decided a control might be needed on the allocation of petroleum supplies. This would ensure equitable distribution of all petroleum products to wholesalers. The Energy Sector, in conjunction with other departments, recommended the formation of an Energy Supplies Allocation Board. A bill to establish this board was introduced in the House of Commons on December 3, 1973, and received Royal Assent on January 14, 1974. The board, under a Parliamentary declaration of a national emergency caused by energy shortages, has powers for the mandatory allocation of energy supplies and to implement rationing if necessary.

On December 6, 1973, the Prime Minister placed a proposal before the House of Commons to set the basis for a new national oil policy. This is designed to create a national market for Canadian oil; a pricing mechanism that will provide incentives for the development of oil resources; increased returns and revenues that result from higher prices used in a manner conducive to security and self-sufficiency; the establishment of a national petroleum company, principally to expedite exploration and development; the early completion of a pipeline to the Montreal area, and intensification of research on oil-sands technology. It was also decided at that time, in consultation with the provincial premiers, to continue the freeze on oil prices until March 31, 1974.

At the First Ministers' Conference on Energy in January, 1974, the ministers reached a decision that the increase in oil prices resulting from higher oil taxation overseas that was effective January 1, 1974, should be "cushioned" by federal payments. To accomplish this, $240 million was allocated from the department's supplementary estimates for payments to oil importers in the first quarter of 1974. This enabled the importers to restrain price increases in an amount of about $4 per barrel. Such increases would have been passed on to the consumers in eastern Canada, had the oil-import-compensation program not been put into effect. The Energy Sector developed procedures for the administration of the oil-import-compensation program in early 1974 and administered the program during the year.

In March, 1973, crude-oil export controls had been instituted because market demand for Canadian oil in the United States was such as to threaten adequacy of supply within Canada. Similarly, export controls on oil products were started in June, 1973.

In the autumn of 1973 the Energy Development Sector was involved in the analysis of the potential effect of the Arab oil embargo on supplies of crude oil and petroleum products in Canada. The sector participated in an interdepartmental committee which examined options to improve the supply situation and recommended courses of action to the Cabinet.

The sector has continued to serve as the secretariat for the Task Force on Northern Oil Development. During the year preparations on an interdepartmental basis were made for the examination of an application for construction of a natural-gas pipeline along the Mackenzie River valley by Canadian Arctic Gas Pipeline Limited. This application was subsequently filed on March 22, 1974.

Studies also proceeded on the production and transportation of natural gas from the Arctic Islands via a route along the west or east side of Hudson Bay.

The department is continuing with an oil-and-gas resource inventory, and during the year further work was done by the sector, in co-operation with the Geological Survey of Canada and other government agencies, to define potential resources of oil and gas in Canada.

In accordance with the Prime Minister's statement on December 6, 1973, $40 million is to be made available for research and development of the oil sands in co-operation with the Alberta government.

In early 1974 *the uranium industry* experienced a dramatic shift from a buyer's to a seller's market. The price for uranium rose, and this, combined with the increased demand from users in Canada and overseas, will trigger an increase in exploration in Canada. As a consequence uranium producers are now coming into their own after being in a slump for many years.

The Minister and senior officials of the department on a visit to the plant of Great Canadian Oil Sands Ltd.

In early 1973 the sector participated in a study to define the government's position on proposals that a uranium-enrichment plant be built in Canada. The Minister released a statement on August 1, 1973, in which he stated that an enrichment plant could not be considered an essential national project in Canada requiring government ownership or subsidization. However, the Minister also indicated that the government was prepared to assist private industry in acquiring the necessary technology from foreign governments if a project was shown to be in the national interest.

At the First Ministers' Conference on Energy in January, 1974, the Minister announced guidelines for discussions with provincial governments and industry on suitable mechanisms to ensure that the domestic nuclear industry will have a long-term uranium supply.

The Minister also announced that the remainder of the government stockpiles of uranium oxide will be held for the domestic market. There have been recent sales to overseas electrical utilities from these stockpiles, including 1,000 tons to Japan and 4,600 tons to Spain.

Nuclear power in Canada during the reporting period also took an upward trend, comparable to the sales picture in the uranium industry. This was spurred on by the decision of Ontario Hydro to have much of its new electrical generation based on the CANDU reactor; the success of the four-unit Pickering nuclear station; the completion of a sale of a reactor to Argentina; receipt of a letter of intent from Korea for the purchase of a CANDU reactor; and the decision of the federal government to build a heavy-water plant at Gentilly.

The department continues its appraisals of *coal supply* for use in eastern Canadian steel mills and by Ontario Hydro, especially as the situation changed from a buyer's to a seller's market, with an unprecedented increase in price, in early 1974.

The sector has participated with the Ministry of Transport in studies on the transportation of western coal to eastern markets. Representatives have also been engaged in a railway study with special emphasis on terminal facilities at Thunder Bay and in some assessments of a coal-in-oil pipeline from Alberta to Ontario.

The department continues to co-sponsor the annual Conference on Coal which, in 1973, was held in Victoria, B.C. Interest remains high in this conference and it is expected to increase with the future possibilities for western Canadian coal in the domestic and overseas markets.

As a follow-up to work that was carried out for the report "An Energy Policy for Canada—Phase I", an analysis of *the petroleum industry's profits* has been completed. It included appraisals of the effect on industry of various proposed rent-collection schemes.

The sector is also looking at methods of financing of energy projects, especially in the United States, where new and novel approaches are being taken. Possible ways of financing Canadian projects, such as the Alberta oil sands and major pipelines, were related to these methods.

Progress has been made during the year in refining available data on the *undeveloped hydroelectric potential* of various regions in Canada. A more accurate estimate of the resources capable of development is necessary to establish better estimates of the quantities of fossil and nuclear fuels that will be needed to provide the additional electrical-energy requirements.

While a 1968 study concluded that tidal developments in the Bay of Fundy would not be economically competitive, there have been in the interim some substantial increases in the costs of alternative sources of energy. A federal-provincial tidal-power review committee is recommending further studies in specific areas.

The electrical section has participated, in close co-operation with the uranium and nuclear section, in assessing the economics of nuclear generation, especially in areas outside the provinces of Ontario and Quebec. The section has also participated in assessment of the capital investments which nuclear developments will require during the next two decades.

Studies were carried out on the advantages of improved regional interconnections from which individual utilities or regions might benefit economically and through which supply could be made more secure. A policy was subsequently approved and announced at the First Ministers' Conference on Energy in January, 1974. This encourages regional interconnections through federal grants for interconnection studies and loans for up to 50 per cent of the construction cost in approved cases.

Specific application of this policy is being discussed with the Province of Prince Edward Island in connection with an underwater cable link to the mainland and with the Province of Newfoundland and Labrador in connection with the proposed development of the Gull Island hydroelectric site on the Lower Churchill River.

The Nelson River Transmission Agreement between Canada and Manitoba, under which Atomic Energy of Canada has built a high-voltage direct-current transmission line, has reached the point where the equipment associated with the initial phase of the development has been declared to be in service. Negotiations are proceeding on a basis for extending the provisions of this agreement to cover subsequent additions to the development.

Discussions took place during the year with the Canadian Electrical Association on a co-operative research program which would involve all of the Canadian electric utilities. The federal government has offered financial participation in the initial stage of the program. Negotiations are continuing to develop this into a permanent program which will complement the R&D support provided by the Department of Industry, Trade and Commerce.

Members of the section continued to take part in activities of the Canada-USSR Electric Power Working Group. These included a seminar in Leningrad on construction methods in cold climates and mechanical aspects of electrical transmission lines. The seminar was followed by a technical tour in Siberia. The Soviet members of the group visited Canada in September, 1973.

Several members of the section participated in a mission that travelled to China in order to look for opportunities of marketing Canadian electrical equipment.

The issuance of *Canada Oil and Gas Permits* was suspended on March 21, 1972, pending review of land regulations, and no permits were therefore issued during the fiscal year 1973–74. Some 285 permits comprising 7.5 million hectares (18.6 million acres) were returned to the Crown during the year, including 131 deep-water permits covering 3.3 million hectares (8.2 million acres) on the continental slope off Labrador and 39 permits comprising 1.2 million hectares (2.9 million acres) on the Labrador Shelf. On March 31, 1974, the government administered 4,949 permits covering 132 million hectares (326 million acres), 85 per cent of which was sea bottom off the East Coast, the region of greatest exploration activity.

Revenues from "offshore lands" during the fiscal year amounted to about $709,600, an increase of 52 per cent over 1972–73.

During the fiscal year, exploration for oil and gas proceeded at a moderate pace off the East Coast and in Hudson Bay; there were no exploratory activities off the West Coast pending a review of federal-government environmental policies in that region.

During the year, work was completed in conjunction with the Department of Indian and Northern Affairs on a draft of new Drilling Regulations and a start was made on new Production Regulations. Both sets of regulations will be promulgated under the Oil and Gas Production and Conservation Act.

Fifty-one separate geophysical programs involving 74,000 km (46,000 line miles) of seismic surveys were undertaken during the year off the East Coast and in Hudson Bay, using 15 vessels and costing an estimated $15 million.

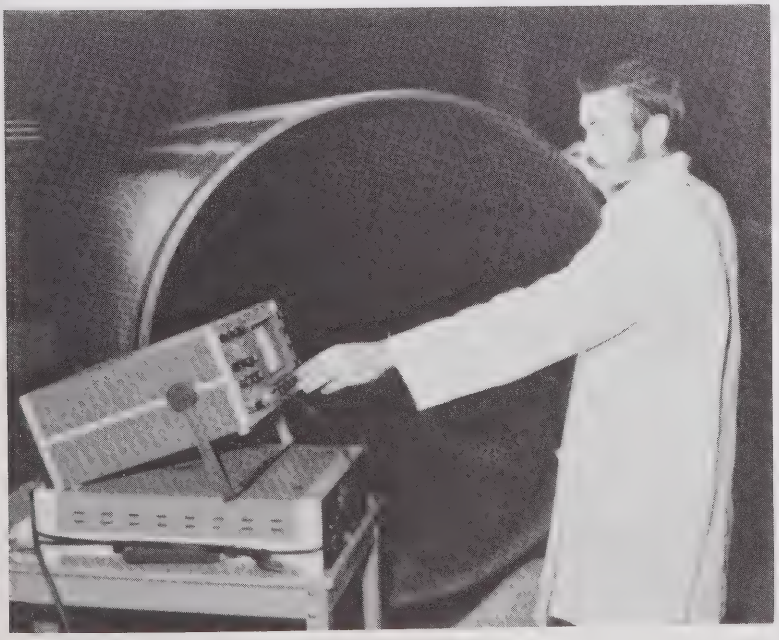
Off the East Coast, 27 wells were drilled at a cost of about $65 million, including 8 wells on the Scotian Shelf, 15 on the Grand Banks, 2 in the Gulf of St. Lawrence and 2 on the Labrador Shelf. This brought the total number of East Coast offshore wells to 85. As many as 6 drilling units were active, including 4 semi-submersibles.

Exploratory drilling resulted in two possible discoveries and one non-commercial show of hydrocarbons. On the Labrador Shelf, there were favorable indications of hydrocarbons in a well 40 miles off the Labrador Coast north of Hamilton Inlet. Due to the lateness of the season this well, drilled by the advanced-design dynamically-positioned drilling vessel Pelican, could not be tested, and so the full significance of the find will not be known until the summer of 1974.

Revenues for the year from federal leases in the provinces amounted to about $440,000, largely from production royalties, and constituting an increase of 10 per cent over 1972–73.

During the year the United Nations Seabed Committee, to which the Resource Management and Conservation branch has continuously provided representation, held its last meeting in Geneva, Switzerland, concluding a series of sessions that have taken place over the last six years and have dealt with a wide-ranging spectrum of matters pertaining to international law in the oceans. The work of this committee having been completed, negotiations proceeded to the Third Law-of-the-Sea Conference to be held in Caracas, Venezuela, during the summer of 1974. First procedural meetings for this conference were held in New York in December of 1973. Of primary importance to Canada and the department in the forthcoming sessions will be the definition of the outer limit of national jurisdiction over seabed mineral resources, and the nature of the international regime and administrative agency to be set up to govern the seabed beyond this limit.

During the year negotiations with Denmark resulted in an agreement regarding the delineation of offshore boundaries of jurisdiction over seabed resources in the Davis Strait–Baffin Bay region. There were no negotiations with the United States regarding the settlement of conflicting claims to shelf boundaries off the east and west coasts, or with France with respect to the continental shelf surrounding the Islands of St. Pierre and Miquelon.



Mines Branch expert tests sample of pipe for pipeline.

MINERAL DEVELOPMENT SECTOR

The Mineral Development Sector is charged with developing federal policies for mineral resources. The emphasis is on resource use and the contribution of minerals to the Canadian economy. Policy advice is based on systematic intelligence and analysis.

The high level of economic activity in industrialized countries intensified demand for all minerals in 1973. High world prices reflected the level of demand. For many commodities price seems to be approaching cyclical peaks, even allowing for inflationary conditions and currency problems.

Canada is simultaneously a consuming nation and a producing nation; an industrialized country and a developing country. Consumers seek security of supply and access to resources on favorable terms. Producing countries want better returns from mining, either in the form of financial returns or the extra benefits from further processing of resources.

Political and economic events are rapidly transmitted to other centres these days as communication is almost instantaneous. No part of the Canadian mineral industry, no region, no level of government and few communities are isolated from the swirl of world forces that affect Canada's mineral-export staples (copper, nickel, zinc, lead, iron ore, molybdenum, potash, gypsum, and the precious metals). To these may be added smelter products such as aluminum.

As a nation, Canada produces an exceptionally wide range of minerals. Two-thirds of all minerals produced are exported, and mineral exports comprise nearly 30 per cent of all exports. Consequently, minerals are more important to this nation and its economy than is the case for any other industrialized country. Yet Canada is by no means self-sufficient. We import several strategic materials such as bauxite, diamonds, chromium, manganese, and tin.

The two main controls affecting international economic co-operation are the *General Agreement on Tariffs and Trade* (GATT) and the International Monetary Fund. Negotiations on the former are to take place in 1974. The Mineral Development Sector is engaged in economic studies of the effects of mineral tariffs within the context of the overall Canadian government response. The results of the forthcoming Tokyo round of negotiations will be exceptionally important. The level of mining activity, the use of mineral resources, the further processing of resources and consequently the health and vitality of communities are affected by tariff and non-tariff barriers.

Terrain scientist, member of Geological Survey of Canada, inspects test cut along Mackenzie Highway. The loose, easily eroded soil makes construction extremely difficult.

Temporary bridge (top) and giant culvert (bottom) ready to be installed on portion of Mackenzie Highway, which will become an important artery for the development of the natural resources of Canada's North. Several of EMR's sectors—Mineral Development, Energy Development—are involved in policy development for the management of northern resources along with the conservation of the environment.

Most people recognize that mineral commodities were unequally distributed by nature across the nation; that some communities, regions and provinces are more dependent than others on particular commodities. The location and grade of a particular deposit cannot be changed. In EMR, the Science and Technology Sector works closely with the Mineral Development Sector in situations where it is possible to change the economic circumstances that lead to development: In this regard the sector manages *mineral-development programs,* normally funded by the Department of Regional Economic Expansion, in association with a number of provinces. For example, as a result of the federal-provincial Western Economic Opportunities Conference, the need for expansion and diversification of western iron and steel production was recognized. Steps have been taken to realize this objective. Similarly, the viability of an East Coast steel complex is being examined. In the far north, the sector was assessing the economic feasibility of the proposed lead-zinc mine at Strathcona Sound, the first industrial project of its type in the area.

The ability of the mineral resource base to sustain the economy in future years is vital in any consideration of Canada's future. Initial work in EMR suggests that known and potentially available mineral resources are adequate to meet domestic needs, and allow for continuation of exports. But what do minerals really mean to Canadians? What supplies are required, what employment is generated by the industry and in ancillary activities? What revenues accrue directly and indirectly? Through economic research using "input-out" analysis and econometric models the sector is making progress in this area of concern. In time, there will be better answers to such questions than are now available.

Price levels for commodities and supply-demand imbalances are usually controlled by long-lasting market forces. In other countries, as in Canada, returns from mineral resources can be significantly affected by short-term problems. Too high a price, and the cost of finished goods must rise; too low, and future supplies are threatened owing to the lag between exploration, discovery, investment in development and production. Short-term factors are often resolved by the industries concerned. But to an increasing degree institutional mechanisms are being developed to cope with problems not covered by GATT or in bilateral arrangements between nations or the normal business dealings of companies.

The sector participated in 1973 in the United Nations Conference on Resources that recognized the interdependence of resource producers and consumers. Canada has long been a member of the International Tin Council and is also a member of the International Lead-Zinc Study Group. Both groups have significant capacities to forecast in the short and medium term, an important factor in resolving problems and maintaining a reasonable stability for these commodities. Both include producers and consumers, leading to a balance of rights and obligations in accord with Canadian commodity trade policy. Canada's interest in resources prompted it to accept observer status in the Iron-Ore-Producers Group, and attendance at meetings of the Copper-Producers Group, Mercury-Producers Group, etc.

The Departments of External Affairs and Industry, Trade and Commerce have important responsibilities in international affairs. The sector's role is to provide assessments of emerging commodity problems from a resource-management viewpoint, and to work on the technical committees.

During 1973–74, Canada received mining and trade missions from Poland, Spain, South Korea, and the People's Republic of China, and hosted more than a half-dozen meetings with officials of other countries. A fruitful interchange was begun with Poland, as Canadian and Polish government officials and mining experts exchanged visits. As a result, the groundwork has been laid for exchanges of mining expertise and expanded trade between the two countries.

On mineral-resource-management problems, views are exchanged between countries at the ministerial and official levels, through missions, conferences, and contact with agencies. The special involvement of corporations domiciled in the U.S., Japan, and the EEC in Canadian mineral resources provide a continuing basis for dialogue on markets, investment, price and supply.

Involvement in these types of activities requires the sector to maintain a strong analytical staff. A wide-ranging intelligence of mineral affairs both domestic and foreign permits a rapid response by the sector to questions of the day, and provides the basis for involvement in longer-term problems of mineral-resource management and policy affecting mineral resources.

Periodic reviews are made of the state of the mineral industry in Canada to help other parts and levels of government, industry, and the public get the information they need. A digest is published annually in the form of the "Canadian Minerals Yearbook." A special publication of topical interest for 1973 is entitled "Mining and Environmental Law."

The Mineral Development Sector is leading a review of national mineral policy in the federal government. In 1973, the first steps were taken to find the common elements, the ties that bind together different interests within the federal government, the provinces and the mineral industry. The ten provincial mines ministers and the federal government announced a set of objectives that will form the basis for a national mineral policy.

Late in 1973, it was agreed to establish a Canadian Ministerial Conference on Mineral Policy. Its purpose is to provide a governmental forum for consultation on issues that are national in scope. The conference is not viewed as a joint decision-making body, but an important new avenue of intergovernmental communication. Ministers agreed that in 1974 the conference would focus on uranium policy; the respective roles of governments in the control, management and disposal of minerals; and the further development of a national mineral policy. In the meantime, different views, sincere views and above all concerned views are being expressed as to the issues that should constitute a strategy for Canada in today's world, in harmony with Canada's resource endowment, and the needs of regions.

The Centre for Resources Studies at Kingston, Ontario, was established on October 1, 1973. It is under the jurisdiction of Queen's University and sponsored by the university, the Department of Energy, Mines and Resources and the Canadian Mining Association. The purpose of the Centre is to carry out high-quality, independent research on those important questions which face the nation in mineral-resource development and mineral-resource policy.

EMR formalized a long-standing agreement with the Canadian International Development Agency to continue acting as CIDA's technical advisor in planning and implementing mineral-related foreign-aid projects. In CIDA-sponsored projects abroad, Canadians are hired by the agency to act as advisors and supervisors of local tradesmen, technicians and managers. In India, for example, a group of Sudbury miners have almost completely changed the work habits of the 5,000 Indian miners at the Khetri copper mine. In what is turning out to be an impressive success story, the Sudbury miners have helped to boost production 400 per cent by demonstrating improved drilling, loading, and tunnelling techniques, and by suggesting a bonus system that spurred the miners to double their efforts.

In 1973–74, EMR aided CIDA in planning instruction for miners in India and mine projects at various locations in Burma, Tanzania and Malaysia, and helped to recruit Canadian professional personnel to supervise these projects. Some 35 training programs in Canada were organized in mining technology with UN or CIDA fellowships. In the past, nine out of ten UN sponsored trainees in the geological sciences, mining and metallurgy were sent to the United States. Today, most UN trainees are being sent to Canada for practical experience.

Members of the Geological Survey of Canada inspect core of subsoil obtained in Northwest Territories. Study of soil content and permafrost penetration help scientists determine the capacity of the soil to support engineering and other projects.

Users of aerial photography can now study microfilm showing complete aerial coverage of Canada and microfiche index cards through viewers like these at the National Air Photo Library. The system facilitates ordering of aerial photography and reduces storage space.

SCIENCE AND TECHNOLOGY SECTOR

Surveys and Mapping

The growing importance of exploration and development of fossil fuel resources in the Arctic and northern Canada requires adequate surveys and topographic maps. During the fiscal year 1973–74, the Surveys and Mapping Branch began to step up its program in the north to serve these needs, and activities over the next several years will emphasize work in these frontier areas.

The major products of the Surveys and Mapping Branch are accurate topographic maps, aerial photographs and data from a national network of survey control points, precisely established and maintained by government geodesists. These are basic tools for the development of Canada's resources and have always been essential for many industrial, scientific, educational, legal, engineering and tourist-industry purposes.

A principal highlight for the branch during 1973–74 was the appointment of Raymond E. Moore as director in July, 1973. He replaced Dr. S.G. Gamble who was appointed Assistant Deputy Minister (Administration) for the Department of Energy, Mines and Resources.

Total budget for the Surveys and Mapping Branch during 1973–74 was $17,506,000. Of that, $5,458,000 was spent on control and legal surveys; $7,997,000 on mapping services; and $2,271,000 on distribution of technical information, with $1,760,000 being recovered through the sale of maps and air photographs. A sum of $70,000 was allocated for feasibility studies and contract management of external-aid project for the Canadian International Development Agency (CIDA), and the balance of the budget went for administration.

During 1973–74, about 3,000,000 maps were sold through the Canada Map Office, and almost 16,000 requests were received by the National Air Photo Library for air photographs.

A major responsibility of the Surveys and Mapping Branch is to get information to professional clients as quickly and as efficiently as possible. Important steps toward this end were taken in 1973 when the branch developed a new data-base system aimed at quick response to requests for new mapping, particularly in the far north. Available topographic maps for this region are mostly reconnaissance types at the scale of 1:250,000. This map scale is adequate, unless some form of resource development occurs. Not knowing where the demand for the more detailed 1:50,000 map scale may occur, the branch has stored in the data-base system co-ordinate data generated from aerotriangulation, which may be drawn upon for rapid map compilation, as the need arises.

Young geologist on traverse checks her bearings before continuing. It is no longer rare to find women in geological field parties.

Such a system allows a selective choice of information for production of a topographic or line map, or a photomap, depending on the user's needs. It also cuts the time needed to process requests from four years to one year for a color map, three to four months for a monochrome map and even less time for an emergency printout. The branch spent $500,000 to begin the program which, during 1973–74, processed into the bank enough information for 800 maps. The data bank will be completed by 1979. An index is available for the content of the bank, and is regularly updated.

There will also be more use of *monochrome maps,* as opposed to the full-color topographic-series maps, so topographic map information can reach the public faster. During 1973, this new emphasis doubled production of topographic maps over 1972. Of the 1,223 maps produced in 1973, 549 were monochromes.

The National Air Photo Library has finished *microfilming the complete aerial coverage of Canada* for easy reference as another service to the public. Cassettes of microfilm containing up to 2,000 images are available. Index maps showing relative ground positions of the photographs have been placed on microfiche, with up to eight index maps per fiche. Major users can buy these cassettes and cards for their own use, or they may view them in the library to order the prints they want. The system reduces the amount of space needed for archive storage and provides a quick reference for ordering prints.

During 1973, microfilming of legal-survey data was also undertaken. The data were obtained from surveys of federal lands, including Indian lands, done on request from other federal departments, and they are available to the public.

The method of establishing horizontal control by measuring, from points on the ground, the Doppler frequency shift of satellites is being used extensively in *geodetic surveying,* particularly in Arctic and offshore areas. Geodetic surveying establishes horizontal control (latitude and longitude) and vertical control (the exact height above sea level) of selected points across Canada to extend and densify the national network of survey control points. This network is essential to accurate mapping by both government and private mappers. The Doppler assessment was done by the University of New Brunswick which, with the help of the Surveys and Mapping Branch, established 21 Doppler stations from the Atlantic to Manitoba. The Doppler method is based on the principle that electromagnetic waves coming from a moving object appear to undergo a frequency shift in relation to a stationary observer. The position of a Doppler ground station can be calculated by recording this fequency shift, because the position of the satellite is known in terms of latitude and longitude at all times.

The success of the Doppler method means an end to the aerodist in the branch's geodetic surveys. This method was employed for the last time in 1973 to establish horizontal control in northern Ontario and northern and central Manitoba, completing coverage of this area suitable for mapping at a scale of 1:50,000. The aerodist is an airborne-assisted electronic distance-measuring device that measures the amount of time it takes for a radar beam to bounce from an airplane to two ground stations and back again as the aircraft passes midway between the stations. From this, the distance from airplane to station is calculated and then the distance between the two stations. The branch has used the aerodist method for the past 10 years, and it has greatly reduced the cost and time of surveying Canada's wilderness areas.

In its geodetic work, the branch established 1,600 new bench marks across Canada for vertical control during 1973–74. One of the most important projects, the levelling along the Mackenzie River valley begun in 1972, continued the following year. The branch also went ahead with its work in horizontal control in British Columbia, using, for the first time, a first-order traverse to establish primary control in a large area of the province north of Prince Rupert between the Alaska Highway and the Alaska boundary. In a first-order traverse, surveyors measure the distance between two points by using electronic distance-measuring devices and angular measurements. This is a departure from the traditional method of calculating distances by triangulation, and, because it reduces both the time and money required to survey, it will probably be used more in the future. In all Canada, horizontal-control work established a total of 99 first-order and 320 second-order horizontal stations during 1973–74.

The International Boundary Commission began the task of replacing stone cairns of the Alaska–Yukon triangulation with more permanent marks during 1973. This was necessary because these stations are being used more and more as surveying reference points by those doing surveys for resource development in the area.

A readjustment of the national network of horizontal control will begin during 1974–75 in Canada following an understanding in 1973 with the United States and Mexico to develop a more uniform survey control network for the whole of North America. Over the past few years, geodesists have found that there are definite distortions in the network. This is because distances measured by the new high-accuracy electronic distance-measuring devices do not conform with data from older surveys in which distances were calculated by triangulation. Thus, resurveying in the regions where triangulation was used followed by computer readjustment of the data to conform with other regions surveyed is essential for an accurate, uniform national and international network of survey control points. The program in Canada will probably take 10 years to complete.

During 1973–74, the Surveys and Mapping Branch published several new products and developed new formats for some maps to make them more acceptable to the public. The fourth edition of *The National Atlas of Canada* was one of the most important new publications. The Atlas, a collection of 334 multicolored maps, 400 graphs and explanatory texts on 266 pages, was completed in the looseleaf form in both English and French in 1973. A contract was also signed early in 1974 with a private publisher for the production and distribution of a bound edition in the fall of 1974. The publication provides an authoritative graphic summary of Canada's physical setting, human geography, resources and economy during the past decade and is a major national reference work.

In the production of *aeronautical charts*, a new publication, RNAV Ottawa–Montreal, was published for the new STOL service between those two cities. A new format for the VFR (Visual Flight Rules) terminal area chart was developed, and a new northern supplement and IFR (Instrument Flight Rules) handbook were published.

Other map products new in 1973 included a map of the Yukon Territory at a scale of 1:1,000,000 and a resource atlas of Newfoundland produced, on request from that province, to coincide with Newfoundland's 25th anniversary as a province of Canada.

On the whole, 3,600 maps were produced—an increase of 25 per cent over last year. Copies printed amounted to 10,000,000. Of these, 1,223 were of the topographic series, 110 of which were produced by the Winter Works Program in Vancouver, now in its third year. Automated cartography, the production of maps with the aid of computers, made up 10 per cent of the branch's production of topographic maps and general maps of Canada. Such automation will gain more impetus in the future as part of a general increase in map production to keep up with Canadian development.

A program for the computer adjustment of blocks of aerial photographs was developed by branch engineers during 1973 and has been accepted as standard procedure by private map producers. The adjustment reduces the need of a great number of horizontal control points throughout the whole block by using measurements of selected points along the perimeter only. The system also reduces the cost of map production.

A special light-weight tower was developed and tested in 1973 by the International Boundary Commission to be used in precise angular measurements by survey teams in the field. The easily transported tower weighs less than 360 kg (800 pounds), comes in five-metre sections that rise to a height of 20 metres and is designed to do the work of much heavier towers based on a design that is 50 years old. The new tower is constructed to carry a theodolite and certain electronic distance-measuring devices. It is placed inside another light-weight tower, developed during the past year by a private manufacturer, which supports the surveyor so that his movements do not disturb the instrument.

Geological Survey of Canada

The Geological Survey of Canada entered the 1970's with a considerably expanded mandate. This derived in large measure from the new emphasis on the protection of the natural environment and the preservation of ecological patterns, on the one hand, and on the need for national self-sufficiency in mineral resources, especially energy resources, on the other.

This led the Survey to expand very greatly its investigation of terrains, from an engineering and conservation point of view, the probing of the ocean bottom, near shores and on the continental shelves, and its inventory and prognosis of existing and probable mineral resources.

Along with this work, the Geological Survey continued to map the bedrock geology of Canada and to study the processes that have led to the formation of the Canadian landmass and whose understanding is essential in the search for valuable deposits.

The total budget of the Geological Survey in the fiscal year 1973–74 was $19,830,000, of which about $600,000 was contributed by other federal departments (mainly for joint research projects in the Arctic). Of this, field work consumed $4.5 million, and the long-term federal-provincial aeromagnetic surveys, which are let out to contract, $1,130,000. Most of the remainder of the budget went to salaries and equipment.

The appointment of a new director, Dr. Digby McLaren, the former head of the Survey's Institute of Sedimentary and Petroleum Geology in Calgary, occurred during the year. (The former director, Dr. Yves Fortier, became Senior Advisor, Earth Sciences, to the Assistant Deputy Minister, Science and Technology.)

The following projects may exemplify the work of the Geological Survey during 1973–74, as it would be impracticable to give here a description of each of the 493 projects undertaken that year—many of them of equal importance.

Of particular interest both to geological science and to the prospecting industry was a continuation of the *Bear-Slave Geochemical Operation,* started in 1972. This survey, based chiefly on the sampling of lake sediments, covered an area of about 93,000 square kilometres (36,000 square miles) north of Great Slave Lake. The follow-up in 1973 covered an area of 3,800 square kilometres (1,500 square miles), and laboratory and office assessments continue.

Field party of Geological Survey of Canada surveys beach morphology near Tuktoyaktuk, N.W.T., on the shore of the Arctic. (*Inset*) Discussing the day's findings of a geochemical survey near Great Bear Lake.

Loading drums with rock samples collected on geochemical survey at Wopmay Lake, N.W.T.

Geochemical surveys, a relatively recent development in geology, are based on the fact that all metals contained in the earth's crust tend to "migrate." This means that the chemical compounds containing the metals are dissolved by groundwater and are carried along with it, often over considerable distances, after which they may become lodged in rocks and sediments. Thus a mineral deposit will become surrounded by a "halo" of weaker concentrations. Being very large, the halo is naturally much easier to spot than the deposit itself, especially as the halo may appear at ground level, while the deposit originating it may be buried at considerable depth. However, metal concentrations in the solutions are usually extremely weak, being measured in parts per million, and highly sensitive laboratory methods are required to establish them.

Geochemical surveys have become a valuable tool in geology, as they may give indications of metal potential in certain areas. However, they are not equally useful or reliable in all types of terrain. Areas with dense deciduous forest cover, for example, are poor geochemical areas, as the vegetation processes tend to obscure or distort the readings. On the other hand, the sparse coniferous vegetation of Canada's subarctic regions, such as the area north of Great Slave Lake, was believed to be excellent "hunting ground" for the geochemist—which was borne out by the Bear-Slave operation. A number of interesting anomalies—unusually high contents—were noted, and hypotheses were put forward to explain them. It was found that the general picture indicated by the geochemical survey did not conform readily to the data produced earlier by reconnaissance bedrock mapping; geologists believe that a re-evaluation of earlier, standard surveys may be required. If such a second look should show the anomalies to be associated with siliceous volcanic rocks, the mineral potential would be regarded as high.

The two-year operation was carried out with a small staff, thanks to the high mobility made possible by small aircraft and helicopters. A field laboratory was set up for rapid sample analysis. Parts of the area under investigation were also overflown to provide color air photographs to aid in the geological interpretation.

It was the largest area in Canada ever to be subjected to a geochemical survey of this type. The preliminary report on the operation concludes that the region "is eminently suitable for applied geochemistry; indeed, in places it may be close to ideal."

Chemical analyses also played an important part in another highly interesting and unusual project of the Geological Survey—a sampling of hot springs in British Columbia to assess their *geothermal potential*. The recent crisis in the petroleum market and the general apprehension that traditional energy sources may become strained or depleted has naturally directed attention to untapped sources. The so-called hot springs which are found in regions of recent or current volcanic activity are such a potential source. In Canada, hot springs occur mostly in the geologically young and active mountains of British Columbia.

Until now, precise data on British Columbia's hot springs have been scarce, and the preliminary report on the survey states that "the geothermal potential of western Canada is impossible to assess on the basis of existing data. Several Quaternary volcanoes (i.e., those no older than about one million years) in British Columbia have produced lavas of an age and type commonly associated with hydrothermal fields elsewhere, but no active fumaroles or boiling springs are known in Canada." Of course, warm water issuing from the ground may indicate boiling water at depth; but this will not be verified without detailed investigation.

The chemical composition of the water provides evidence of the conditions at depth—water with a high content of silica usually indicates a recent or hot volcanic environment, whereas a high content of carbonates indicates an older, cooler environment.

Therefore the sampling program carried out during the 1973 field season embraced chemical analyses as well as other techniques on approximately 50 thermal springs in British Columbia. Some sampling was also carried out during the winter.

There appeared to be no temperature difference in hot springs between summer and winter. One hot spring, located about 160 kilometres (100 miles) north of Vancouver had a temperature of up to 60°C (140°F), and the drill pipe extending into the spring was so hot that the drillers could barely handle it. Even the rocks some distance from hot springs still show high temperatures.

Top: Members of a geological "fly camp" load their gear on an "Otter" for return to base camp. *Bottom*: Geologist uses small sledge hammer to obtain rock samples for geochemical survey.

Top left: Brief pause during helicopter-supported field survey: The geologist makes entries in his note book, while the chopper pilot refuels. *Bottom left*: Making notes during geological traverse. *Right*: Terrain scientists collect sample of beach material on the shore of the Arctic.

The way in which geothermal energy may be converted to practical use in Canada is not yet certain. A problem is also presented by the lack of legislation covering access to and use of thermal springs. Mining legislation has not so far concerned itself with these natural phenomena, and this question will have to be dealt with before development can begin.

The legacy of recent geological activity is also the subject of another type of investigation carried out by the Geological Survey in 1973–74—that of the *landslide-prone areas* of the Ottawa valley.

The so-called Champlain Sea—a large invasion of the sea into the St. Lawrence River valley and adjacent regions about 10,000 years ago—left behind large amounts of sea-bottom sediments, mostly clay. In many parts of the area these sediments have since been washed away, but where they remain they often represent a considerable hazard, as they have the capacity to store up large amounts of water, which may cause them to turn into sliding mud with little warning. The disastrous landslide at St. Jean Vianney in 1971 and the lesser slides at Templeton and Chelsea in 1973 (in Quebec) and the 1971 slide at Casselman (Ontario) all started in these Champlain clays. Geologists hope that they will be able to classify soils in the area affected by the degree of landslide danger, so that builders and homeowners will be left in no doubt as to the risks they may be taking.

What makes such work even more important is that certain other areas of Canada also have soils dating from the same period and having the same characteristics. This applies, for example, to thousands of square kilometres around the southwestern part of Hudson Bay. The only reason why landslide damage has not been reported from that area is that settlement is so sparse there. If enough information can be obtained before the advent of development—e.g., pipelines or other transportation routes—construction may be planned in such a way that slide dangers will be averted.

The ocean and seabed off Canada's east coast may well become a large new source of mineral wealth, in addition to the wealth in fishes and other sea food. In order to understand the peculiar marine environment and the forces that continue to shape it, the Atlantic Geoscience Centre of the Geological Survey has been carrying out a broad range of investigations in marine geology.

One such study, in the summer of 1973, concerned past and present *processes affecting the nearshore environment* in the Strait of Canso and Chedabucto Bay, Nova Scotia. Not only has that area seen important industrial development in recent years, due in large part to the construction of the causeway linking Cape Breton Island to the mainland, it has also been the scene of a disastrous oil spill from the tanker "Arrow" in 1970, which fouled many of the beaches.

Geologists set up a temporary laboratory in a Port Hawkesbury school gymnasium and had a small vessel at their disposal for surveys and sampling. Participating in the program were 31 scientific and technical staff representing five research agencies from government and a university. Activities included comprehensive bottom sampling, water sampling for suspended solids and dissolved constituents, a shallow seismic survey and coastal mapping.

The scientists found that the construction of the causeway had divided Canso Strait into two distinct oceanographic environments with pronounced differences in the salt content and temperature stratification. The quality of the bottom sediments and the water has been affected by industrial wastes from the industrial park at Point Tupper. Living foraminifers—tiny unicellular animals that populate the oceans in vast numbers—were completely absent, and the water was highly turbid and contained traces of metals. Much of the coastal environment of Chedabucto Bay was still affected by the residue of the oils from the "Arrow" disaster.

The study sheds new light on the effect of industrial activities on marine ecology.

Projects that do not take place in the field but that are at least of equal importance are the *evaluations of Canada's fuels and minerals* that are being carried out by the Geological Survey's Institute of Sedimentary and Petroleum Geology in Calgary and by head office staff in Ottawa. By using all available data on geological settings, in Canada and abroad, that are known to be favorable for the occurrence of certain types of fuels or ores, along with data from oil and mining companies, economic geologists engage in "plays" that may yield better assessments of our energy and resource prospects, thus helping to plan appropriate regulatory measures.

In order to provide the broadest possible base for such evaluations, the federal government is negotiating with provincial governments—which carry out their own geological studies—for a joint evaluation program covering all non-renewable resources as well as terrain types.

Mines Branch

The Mines Branch is a large laboratory and pilot-plant complex conducting research to develop new and better methods of extracting minerals and fuels from the earth's crust and processing them into useful products. Today's twin demand for new sources of energy and minerals and a clean, attractive environment are reflected in the research and development work of the Mines Branch. As most of Canada's high grade and readily accessible mineral deposits are already being mined, research emphasis at the Mines Branch is placed on developing recovery techniques for ores and minerals that present problems because of low grade, impurities, or complexities of mineral composition. The total budget of the Mines Branch in the fiscal year 1973–74 was $14,116,000.

Dr. Donald Coates, formerly the head of the branch's Mining Research Centre, was appointed director of the Mines Branch, succeeding Dr. John Convey, who was recently appointed Senior Adviser on Mining and Metallurgy.

In 1973–74 the "energy crisis" struck Canada, underlining the importance of extending existing energy reserves as well as developing new sources of energy. Fuels research at the Mines Branch includes a comprehensive evaluation of the quality of Canada's fossil fuels and the development of refining methods for the low-grade petroleum of the *Athabasca oil sands*. The enormous potential of the sands cannot be tapped until efficient, economical techniques can be developed for separating the oil from the sand, and upgrading the oil for commercial use. Some of Canada's low-grade crude oils contain unwanted sulphur and traces of nickel and vanadium. Mines Branch fuel experts have developed a "hydrocracking" process which eliminates much of the nickel and vanadium, reduces sulphur content, and increases the fuel yield by about 20 per cent. In this process, the production of waste coke is virtually eliminated, and the liquid product has a wide range of fuel uses. The process is now ready for testing on an industrial scale.

Machine feeding excavated tar sands onto conveyer belt, at Athabasca Tar Sands. EMR is advising the government on development and financing of these and other energy sources.

As energy needs grow and the cost of oil and gas continues to rise, coal will be used increasingly as a source for thermal electricity, especially in the coal-rich western provinces. During the year, the Mines Branch continued work on a federal-provincial project to determine the amount of *lignite coal* in the Ravenscrag Formation in Saskatchewan that can be used for thermal power production for the next 20 years. About 1,500 samples have been analyzed annually for the past two years, and the assessments and recommendations are expected by the end of 1974. Discussions are going ahead with the provinces concerning similar projects.

In addition to developing the technology for opening up new sources of fuel for the future, the Mines Branch is also seeking the most efficient methods of using existing energy resources. Combustion experts performed a series of winter *driving tests* on an assortment of automobiles under highway and stop-and-go city driving conditions to measure fuel economy and pollution emissions. It was found that many strategies could be followed to improve gasoline mileage and reduce significantly pollution emissions from current designs of engines. Several fuel-economy devices attached to the engines were tried out, and some increased gasoline mileage considerably.

nes Branch experts have developed w methods for safely increasing the dients of open-pit mines such as this e, thereby reducing the overall size the pit and making excavation more onomical.

After many years of research the Mines Branch has also developed a "blue-flame" *oil-furnace burner* that reduces fuel consumption by about 10 per cent during a typical winter and is virtually nonpolluting. The burner is now ready to go to the industrial prototype stage and may one day become a commodity item.

Transporting *liquid fuels through pipelines* is another area of Mines Branch expertise. In the future, much of Canada's oil and gas will come from faraway frontier areas, and reliable, durable pipelines will be a necessity. Accordingly, metals research at the Mines Branch is now focusing on ensuring the structural soundness of pipelines for use in the Arctic. A major pipeline project has been launched to study the behavior and use of metals and alloys in the harsh Arctic environment. Branch metallurgists are testing pipeline metals for strength, weldability, corrosion, cracking, brittleness, and ductility in order to select the best materials for the job. During 1974 the branch will produce a monograph on metals and alloys for use in the Arctic, and a report on the structural suitability of the proposed pipes for the Mackenzie Valley pipeline.

Mining research is aimed at maximizing ore production from both open-pit and underground mines with minimum cost and environmental disturbance. The second year of a five-year $4-million project to optimize the design of the rock slopes of open-pit mines was completed on schedule. The goal of the project is to reduce the excavation of waste rock from open-pit mines by more than ten per cent a year—a reduction of some 35 million tons that could save the mining industry up to $50 million annually. In 1973 the total budget for the project was $650,000, of which $450,000 was contracted out. At the completion of the project, an engineering manual on pit-wall design for the use of operating engineers will be produced.

Mine safety is also a major concern of the Mines Branch. Bigger machines and deeper mines have produced an underground working environment demanding more attention to pollution by dust, radiation, noise and diesel exhaust fumes. At branch laboratories in Ottawa and Elliot Lake, scientists are testing the sources, effects and methods of controlling harmful components of mine air. In co-operation with a private research foundation, the branch has modified a dust sampler which gives a more accurate reading of dust levels in metal mines. These instruments are now being tested in several mines.

Particulate emissions from diesel engines used in underground mining are also being studied to determine the effectiveness of water scrubbers and afterburners to remove harmful carbon particulates. Test results to date will provide new guidelines for mine-ventilation design. Branch scientists are also developing monitoring systems for an early warning-detection system to prevent explosions.

Over the years the Mines Branch has developed a sound reputation for its close working relationship with industry. An example of this effective relationship was illustrated in 1973 with the completion of a project to develop a process for the *production of spodumene,* a lithium-bearing mineral used in the manufacture of heat-resistant glass. Branch scientists developed a difficult and complex flotation process for the spodumene, and industry applied this laboratory work to pilot-plant scale. The branch has obtained Canadian and American patents for the process, which is now ready for commercial application.

The Mines Branch is also working closely with industry on the development of a unique *electric smelting furnace* for iron ore. After a decade of research in branch laboratories, a contract for $303,314 has been awarded to a major Canadian steel company to further develop the process under industrial conditions. This novel smelting process lowers energy needs, alleviates pollution problems, increases output and allows the use of coal as a source of carbon instead of the more expensive coke that is required for blast-furnace smelting. In this process, the off-gases from the electric furnace are used within the overall smelting process, reducing energy needs by about 30 per cent.

Industrial interest in the "shaft-electric furnace" has become keen in the last few years due largely to the increasing scarcity and cost of scrap steel as furnace feed, increasing energy costs, and a growing awareness of industrial-pollution problems. Since the shaft-electric furnace can be operated economically in smaller units than is possible with blast furnaces, such a unit could find use in small or medium-size steel plants located in areas where the population is too small to support large integrated steel works.

Other significant research related to steelmaking is aimed at finding a substitute for expensive and increasingly scarce imported *coking coals*—an essential ingredient in the smelting of iron ore. Western Canadian coal could provide a major supply of low-volatile coking coal, but there are problems in transporting western coal economically to major steel producers in the east. One solution is to transport coal in an oil slurry through a pipeline. In this way, both thermal coal for use in electric generating stations and coking coal could be transported over long distances. Branch researchers are studying methods for separating coking coal from such coal-oil slurries without deterioration of the coking characteristics. So far, laboratory tests have shown that separation is technically feasible.

In the field of *mineral sciences*, a whole range of physical, chemical, crystallographic, and magnetic studies determine mineral characteristics important to the extraction and processing of mineral ores. A promising new project was started during the year to assess the potential of sophisticated image-analysis equipment for a whole range of mineralogical research. Using this "image analyzer" it is possible to determine quickly and efficiently the proportion of each mineral in an ore sample, and the size distribution of these minerals. This information determines the minerals which must be concentrated in order to recover specific elements, and the size to which the ore must be ground to liberate the mineral. The image analyzer makes routine tasks that are long and complicated with traditional methods.

Branch scientists have used the image analyzer successfully to analyze many ores, including a *fine-grained zinc ore* of a type that occurs in New Brunswick but that is not found in any currently producing mine in Canada. It does, however, occur at the Santa Lucia zinc deposit in Cuba, and Mines Branch expertise was enlisted by the Canadian International Development Agency (CIDA) to help with finding a suitable method for processing the ore. Studies have shown that the fine-grained ore of New Brunswick and Cuba requires very fine grinding to achieve optimum mineral separation. The Mines Branch also assessed a silver deposit in Morocco at the request of CIDA and found the ore of sufficient potential to support a small mining operation.

More than 30 per cent of the total Mines Branch research budget is assigned to various projects related to environmental improvement, some of which have already been mentioned. One of the goals of the branch is to develop new methods of processing and recovering mineral resources that will reduce environmental problems. In 1973–74, research continued on *hydrometallurgical methods* of processing sulphide ores that avoid the sulphur-dioxide pollution caused by conventional smelting processes.

The initial phase of hydrometallurgical treatment is leaching. The ore is treated with a liquid that dissolves the valuable metal components. Once in solution, the metal products can be separated and ultimately recovered by such processes as solvent extraction, ion exchange, and electrolysis. The sulphur produced as a by-product is nonpolluting and has commercial potential. Branch metallurgists have developed hydrometallurgical processes, some simple and some more complex, for the treatment of nickel-copper-iron sulphide concentrates that can recover nickel (along with associated cobalt) and copper to produce either crude or refined metals. Such processes, in addition to being nonpolluting, would prove especially useful when the size of an ore deposit is too small to justify the costs of building a conventional smelting complex. A plant using hydrometallurgical processing could be built at the mine site.

In another area of environmental research, studies are continuing on *converting mineral wastes* into useful products. In 1973–74 processes were developed for: the manufacture of mineral-wood insulation from asbestos tailings, production of dry-pressed brick from iron-mine tailings and production of calcium-silicate building bricks from the residues of magnesium metal production. Branch scientists are also studying methods for recycling cans from garbage to reclaim tin and steel components. Successful results of this new project could lead to far wider applications of scrap-metal re-use.

Not all mineral wastes, however, can be converted into useful products. In fact, most mining and metallurgical wastes end up in tailing ponds and waste dumps, with potential for harm to the environment. To minimize the environmental effects of these wastes, branch researchers are studying a variety of methods for *removing harmful substances* from water, effluents and tailing ponds before they enter drainage systems. Tests were conducted on the problem of water contamination caused by the weathering (exposure to atmospheric factors such as wind, rain, sun) of sulphide-containing tailings from processing mills. Tests were also carried out on the tendency of certain clays to absorb polluting traces of metal from mine-waste waters. During the year research continued on the revegetation of mine wastes. Not only does revegetation prevent erosion by wind and water and reduce the polluting effects of airborne dust and seepage water, but it is more pleasing to the eye than exposed waste dumps. Field-plot and growth-chamber studies were done on acidic mine tailings in the Elliot Lake area to determine the most suitable plants and fertilizers for soil, weather, surface, and sun and wind conditions.

A geophysicist with the Earth Physics Branch measures the declination and dip of the earth's magnetic field near the north magnetic pole off Bathurst Island in the Canadian Arctic. Data from the study were used to calculate the new position of the wandering pole.

Earth Physics Branch

The Earth Physics Branch, during 1973–74, diverted most of its efforts from the regular, continuing programs to urgently required geophysical studies and research projects concerning exploration and resource development in the Canadian North and West.

Generally speaking, the branch studies the seismic, gravitational, geothermal, geodynamic and geomagnetic properties of the Canadian landmass and their relationship to similar data from across the world. These basic geoscience services provide key information for resource development, energy transportation, navigation, telecommunications and national defence and contribute to knowledge of the geological evolution of Canada and geological hazards such as earthquakes. As part of its routine work the branch also maintains a network of seismic, geomagnetic and earth-motion observatories across Canada and produces maps of the gravity and geomagnetic fields.

During 1973–74, the branch operated on a budget of $4,892,000, of which $1,318,000 went to the Gravity Division; $1,369,000 to the Division of Geomagnetism; $1,572,000 to the Seismology Division and $633,000 to administration.

A principal highlight for the year was the appointment of Dr. K. Whitham as director in December, 1973. He replaced Dr. John H. Hodgson who accepted an UNESCO position in the Philippines.

During 1973, the Seismology Division completed a seismic-hazard study for the northern Yukon and the Mackenzie Valley. The study is in three parts. One part, published as "Seismic Risk in the Northern Yukon and Adjacent Areas," is an historical account of seismic occurrences there. The second part, soon to be published, outlines the microseismic events (those too small to be routinely recorded by the division's seismic network) registered during a special six-week experiment in 1972. The third part is a theoretical calculation of what would happen to the ground near a pipeline if an earthquake of a certain size occurred in the area. In the future, similar studies will be done for Arctic areas that show potential for resource development, particularly if that development includes pipelines.

Earth physicist checks the position of a rock core to be used in paleomagnetic survey.

Improvements made at the seismic-array station in Yellowknife, N.W.T., now allow seismic events to be computer-processed there as they happen, thus eliminating the delay caused previously by having the magnetic tapes processed in Ottawa. The station was established in 1962 to do research on discrimination between earthquakes and nuclear explosions. At the station, seismometers are arranged in an array and any ground motion they detect is transmitted to the new computer which monitors, digitizes and analyzes all incoming signals and immediately detects any seismic events. A telephone connection between computers in Ottawa and the Yellowknife equipment scheduled to be established in the near future will make the processed information available in Ottawa within 24 hours.

Early in 1974, the *geothermal unit* of the Seismology Division began to assess the possibilities of geothermal power as a feasible energy source in Canada by shallow drilling in the Lillooet Valley area of southern British Columbia. This region has potential as a source of geothermal power because of the hot springs there and also because it is close to the urban area around Vancouver. This work, conducted with the co-operation of the Geological Survey of Canada, is only part of the unit's program which actually centres on permafrost and heat-flow studies.

Results from a feasibility experiment carried out during the summer of 1973 in the Quesnel area of British Columbia with the *Vibrosis deep-reflection technique* of studying the structure of the earth's crust are encouraging and indicate that the technique is useful for future branch work. The oil industry has used this device regularly to study potential oil-bearing structures to a depth of three to five kilometres, but its use by the branch to 30 or 40 kilometres (20-25 miles) is quite new. This is the first time the division has used the device and the first time it has been tested in an area already geophysically surveyed so that results can be compared with those already established. The technique, which relies upon the reflection of vibrations sent into the crust from the surface, is valuable because the equipment is easily transported by truck. It is also "cleaner" than present techniques, many of which use explosives, and enables seismologists to obtain a more detailed picture of crustal structure.

A team of four geophysicists from the Division of Geomagnetism calculated the present position of the *earth's north magnetic pole* as just north-west of Bathurst Island at 77.1°N, 101.8°W following a two-month trip to the Arctic during the summer of 1973. This is the first time since 1962 that the position of this perpetual wanderer has been established by ground observation. The magnetic pole is now moving about 11.5 miles north and 1.2 miles west per year. This wandering is evidence of secular or slow change in the orientation of the earth's magnetic field. Assigning the magnetic pole a provisional location every five to ten years is essential for the production of magnetic maps and for establishing a pattern of variations in compass readings for the Arctic. Such knowledge is necessary for navigation in the area. Data for the calculation came from four temporary stations set up on sea ice and two permanent magnetic stations at Resolute Bay and Isachsen. The team also established 21 temporary stations in the northeast Arctic to study other aspects of secular change in the earth's magnetic fields.

An important study, based mostly on *paleomagnetic data*, showing the relationship between oil occurrences and climate, nutrients and tectonics (particularly plate tectonics which have governed continental drift through geological ages) was published early in 1974. The paper argues, in brief, that plate tectonics govern the preservation and pooling of oil as well as the formation of oil deposits, which results from a combination of climate, nutrients and water that is suitable to the growth of oil-forming plankton. Paleomagnetic data, drawn from the study of magnetism in ancient rock, are important to the theory of plate tectonics because magnetic particles in many rocks align themselves with the orientation of the earth's magnetic field at the time the rock is formed so that any shift in continental location since that time is indicated if the magnetic alignment of a rock is different from an alignment expected for a rock of that geologic age.

Calculations for the *first geoidal map of Canada* were completed by the Gravity Division during 1973 using the new world gravity standards adopted by the International Union of Geodesy and Geophysics in Moscow in 1971. The map shows the shape of the geoid under Canada which corresponds approximately to sea level and takes into account the curved surface of the earth. It will help geodesists and cartographers to correlate survey measurements made on Canada's land surface and measurements of the geoid as a basis for accurate map preparation. A geoidal map is especially useful in Canada where mapmakers deal with a large landmass and varied topography. The calculations for the geoidal map are accurate to $\pm$ 5 metres as far as measuring the total surface of the earth goes and $\pm$ 1 metre for local measurements. This accuracy is adequate for current needs, but a better knowledge of the geoid will be necessary in the near future to meet the needs of geodesists and geophysicists using improved electronic distance-measuring instruments and satellite Doppler receivers which establish survey measurements by measuring, from points on the ground, the Doppler frequency shift of satellites above (see Surveys and Mapping).

A new edition of the *Bouguer anomaly map* of Canada was published by the Gravity Division in 1973 compiled from some 350,000 gravity observations made on land and sea. Major contributors of information were the Gravity Division and the Atlantic Geoscience Centre. Other important contributions were made by provincial agencies, universities and petroleum and mineral-exploration companies. The new map, which shows gravity variations for most of Canada, is based on the International Gravity Standardization Net (1972) and the Geodetic Reference System (1967) and, in future, information from all gravity stations in Canada will be given in terms of the new international absolute gravity system. Another innovation in producing the new map was the use of automated methods to organize data, convert them into the new system and smooth and contour it.

The Gravity Division acquired two satellite Doppler receivers to help in the *study of polar motion* which has been carried out to date with Photographic Zenith Tubes (PZT's) at Shirleys Bay near Ottawa, Ont., and at Priddis near Calgary, Alta. Like the PZT's, which are an astronomic technique for photographing stars as they cross the zenith, the receivers are keyed to an international program for determining the position of the pole of rotation of the earth. As part of a world-wide network, they observe, every day, at least five satellites that have been put in orbit by the United States to allow receivers to accurately assess their positions in latitude and longitude by measuring the satellite's Doppler frequency shift. The receivers, operated alongside the two PZT's, measure irregularities in the position of the rotational pole to within one metre over a few days. The study is important because irregularities in polar position may indicate changes in mass distribution within the earth arising from major earthquakes. Other practical applications of the study include greater accuracy in geodetic observations, aligning radio telescopes and monitoring deep-space probes.

Geologist and earth physicist on coring project.

Canada Centre for Remote Sensing

The Canada Centre for Remote Sensing was established in 1971 as a branch of EMR. According to official documents, its purpose is "to collect, process, disseminate and develop applications for data applicable to resource management and environmental control of Canadian land and ocean masses, which are obtainable from specialized remote sensors in airborne and space vehicles."

In order to carry out its function, CCRS can call upon a fleet of four aircraft based at the Ottawa airport and equipped with various sensor combinations. It also operates a satellite-receiving station at Prince Albert, Sask., which records imagery from the Earth Resources Technology Satellite, launched by NASA in 1972, ground data-handling facilities in Ottawa and Prince Albert, and an applications laboratory in Ottawa equipped with instrumentation for image processing and analysis.

The annual budget of CCRS is approximately $6 million. Of this, the Airborne Division spent about $2 million and the Data Processing Division (which also operates the Prince Albert Satellite Station and all of the computer installations in Ottawa) spent about $3 million; the Applications Divisions spent about $800,000. The remainder went for administrative and similar expenditures.

Broken down in another way, $2 million of the total budget went for capital expenditures, and $4 million for operating expenditures. Remote sensing is a highly automated technology, and purchase and replacement of computers and other complex equipment absorbs a considerable proportion of the budget.

Now that some two years have passed since the introduction of large-scale and integrated airborne and satellite remote sensing in Canada, the time has arrived for reviewing some of the results and assessing to what extent early promises and expectations have been fulfilled.

Not surprisingly, benefits have been greatest and most obvious in areas peculiar to Canadian geography and settlement patterns. Thus the Arctic, whose vast extent and poor accessibility still raise formidable obstacles to exploration and transportation, is an especially fruitful field for remote sensing. In the summer of 1973, for example, an attempt was made by Donald Fisher & Associates, Prince Albert, to transmit ERTS imagery to ships operating in the ice-infested waters of the Arctic Archipelago. The transmission of the imagery, which showed ice conditions in the Arctic waters, was experimental, and it will be put on a more solid basis in 1974. However, a geophysical-exploration ship managed to avoid costly delays and to save thousands of dollars by being advised of ways of circumventing the ice. If, as is expected, satellite imagery will provide ice coverage that is at least as good as if not better than the visual observations thus far made from aircraft patrols, the patrols may be reduced, at great savings to the taxpayer. It has been estimated that annual savings of $4 to $8 millions can be achieved with present technology in the ice reconnaissance field.

Part of an image obtained by the Earth Resources Technology Satellite (ERTS) over Byam Martin Channel in the Arctic. Such imagery is useful in determining the position and movements of sea ice.

The remote sensing of crops also appears headed for a big future. The "Spring Wheat Project," carried out parallel in Canada and the United States, is aimed at identifying wheat acreage in certain selected areas of the western provinces, from satellite imagery. The project is based on the principle, basic to much of remote sensing, that different types of vegetation have different "spectral signatures," expressed as the relative amounts of solar radiation at a number of wavelengths reflected from an element of the earth's surface. For example, the number of such elements on one satellite image is about 16 million. To analyze such imagery with human observers is obviously impracticable; but a correctly programmed computer can accomplish the work in short order. A team of researchers, drawn from various government agencies, including CCRS and the Department of Agriculture, is now working on ways and means of transforming the data into computer-processable form.

The "Spring Wheat Project," like nearly all other remote-sensing projects, is dependent on three levels of observations: ground observers, who carry out "ground truthing" or spot checks to verify spectral signatures; airborne imagery, often obtained with photographic cameras; and satellite imagery, obtained with a multispectral scanner, a device operating somewhat like a color television camera.

The airborne arm of the Canada Centre for Remote Sensing flew about 300 projects during 1973–74, with imagery obtained over nearly 80,000 line-kilometres (50,000 line-miles). The projects had been requested by numerous user agencies—federal, provincial, university, and private.

Airborne imagery was provided at nominal or no cost to most users during the year, but in order to place this service on a more realistic, self-sustaining basis, charges were set at $5.50 per line-mile in 1974–75 and at $11.00 per line-mile in 1975–76. There will also be additional incidental charges.

New sensors under development for use in aircraft are: a pulsed laser fluorosensor for detection of oil slicks on water; a stabilized camera mount for hydrographic mapping using photogrammetric techniques; a lidar system for airborne hydrographic sounding; and a microwave holographic radar for measuring ice thickness.

It is the policy of CCRS to turn as many remote-sensing operations as possible over to private industry. A major step in that direction will be the letting of a contract for the operation and maintenance of the aircraft now used for airborne missions and presently operated by the Canadian Forces Airborne Sensing Unit. A request for a proposal for such a service has been transmitted to Canadian companies possessing expertise in the field of air surveys, and officials hope that a viable airborne remote-sensing company will result, which may gradually acquire aircraft of its own and enter into independent deals with users.

Another, similar plan calls for the transfer of all the production of black-and-white satellite imagery from EMR's Ottawa laboratories to those of Donald Fisher & Associates at Prince Albert, with CCRS retaining only certain policy controls.

After experimentation with several fairly complex systems for identifying and ordering ERTS imagery, the so-called "ERTSFICHE" has been developed by EMR experts, and it has greatly simplified cataloguing, indexing and dissemination of ERTS data. It consists of microfilm reproduction of imagery, grouped by days and orbit tracks, enabling users to see exactly what each image contains, along with extent of cloud cover, before they order it.

Polar Continental Shelf Project

Polar Continental Shelf Project (PCSP) is the name given to an annually repeated effort on the part of EMR to provide electronic position-finding, air transportation and supplies to Canadian and foreign scientists and surveyors exploring the northern Arctic, where the severe climatic and geographical conditions make it almost impossible for smaller field parties to operate on their own.

The total budget of the PCSP in 1973–74 was $3.1 million, nearly all of which was spent on field activities, the overhead being extremely low. Base camps were kept at Resolute on Cornwallis Island and at Tuktoyaktuk near the Mackenzie River delta. Major field work was carried on from mid-February to mid-October 1973, taking advantage of the warmer weather and long daylight.

The biggest field projects, in terms of men and money, were hydrographic surveys in Amundsen Gulf and in Norwegian Bay; the former ran parallel with a gravity survey. Hydrography was carried out by staff of the Department of the Environment, and the helicopter, fixed-wing, and transportation support provided by PCSP amounted to over $400,000.

Such geophysical measurements and soundings of the sea bottom are an essential basis for further exploration—the search for offshore oil, safety of marine navigation, understanding the geology and the long-term processes that have shaped, and continue to shape, the geography of the Canadian Arctic.

Altogether, the PCSP supported 65 field projects in 1973. Most of the major ones were undertaken by EMR and the Department of the Environment, and consisted of various types of surveys. Among the non-Canadian agencies taking part were several from the United States, one from Switzerland and one from Germany. The Swiss team made climatological observations during the winter of 1973–74, and the Germans excavated archeological sites on Banks Island, discovering interesting and remarkable stone and bone tools and ornaments.

Other investigators studied the animals, birds and fishes of the Arctic, geological and geophysical features of the islands, glaciers, sea-ice behavior, and the effect of exploration and construction on the Arctic environment.

Top: Members of a Polar Continental Shelf Project field party prepare high explosives for a seismic test. *Bottom*: Lowering a diver through a hole in the Arctic sea ice, as part of an oceanographic study.

A colored flare marks the wind direction on a makeshift landing field in the Arctic.

Explosives Division

The Explosives Division is responsible for the administration of the Canada Explosives Act and related activities in the explosives field. One of the main responsibilities of the division is control over all factories that produce commercial blasting explosives, military explosives, blasting accessories, sporting ammunition, fireworks and other pyrotechnics. In addition to ensuring the quality and safety of these explosive products, the Explosives Division also oversees their road transportation, storage, sale and importation. Control is exercised by a licensing system supported by inspections by members of the division. All licenses and permits are issued from the Ottawa office.

The number of factories licensed to manufacture explosives increased from 60 to 66 by March 31, 1974. They produced about 215,000,000 kilograms of commercial blasting explosives compared with 170,000,000 kilograms in 1972–73. Production of fireworks, ammunition and blasting accessories also increased but not to the same degree as commercial blasting explosives.

Since an amendment to the Canada Explosives Act in 1972 restricting the sale of high-hazard recreational fireworks to qualified individuals, the Explosives Division has provided courses to qualify candidates as "Fireworks Supervisors." By the end of March, 1974, about 2,500 persons had attended courses at centres across Canada.

A Bill to further amend the Explosives Act to provide more effective control over the sale, purchase, possession and security of explosives was recommended in 1973 by the division and accepted by Cabinet Committee in February, 1974.

RESEARCH AGREEMENTS

The underlying purpose of the department's Research Agreements is to fund extramural research and development projects that are directly related to the department's mission. Canadian research organizations that are not directly managed by the federal government and that undertake research in the natural, physical and social sciences and engineering are eligible to apply on behalf of individual investigators in their employ.

The intention is to bring many kinds of expertise to bear on the problems of national policy, to apply a multidisciplinary competence to the development of advice to the government and information for the community at large. The branches of EMR, with their disciplinary orientation, are responsible for assessing the proposals which relate to their own objectives and activities, and for monitoring the investigations throughout the life of the agreement.

Research Agreements are made for the following fiscal year, and those made for 1974–75 totalled $861,528. They were concluded with 38 Canadian institutions, and represented a slight increase over the preceding fiscal year.

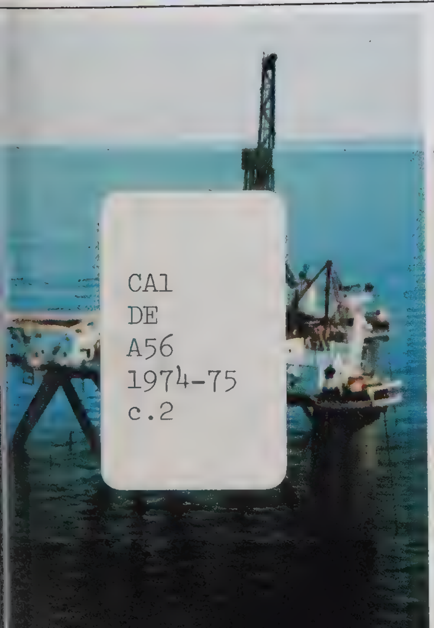
Members of university faculties will again receive the largest proportion of the funds—$769,428, divided among 106 principal research individuals. Other awards are made to members of provincial research councils and specific research institutions.

Typical research projects include:

- the effect of blasting on oil-sand slopes;
- geotechnical properties of the Athabasca oil sands;
- in-situ recovery of oil from the Athabasca oil sands;
- improvement of energy utilization in the transportation and urban use sectors in Canada;
- development of general-purpose computer simulation programs for petroleum reservoirs;
- combined pyrolysis-gasification of coal and wood-waste;
- life expectancy of Canada's oil and gas resources;
- a computer system for storage, retrieval, and analysis of mineral-deposits data;
- regional metallogenic analyses of Nova Scotia and Newfoundland;
- exploration case-history studies of Canadian ore deposits;
- radio-frequency interferometry as applied to ice and permafrost sounding;
- sediment movement in the Minas Basin, Bay of Fundy;
- urban cartography;
- developments in automated cartography;
- local earthquake studies in the Canadian Cordillera.

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Annual Report 1974-75



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Introduction

Throughout fiscal year 1974-75, one economic consideration more than any other dominated the deliberations of governments and the reports of the news media in all parts of the world—energy, the sources of its supply and its price. This was the case in Canada as elsewhere, and because of the nature of the topic and the responsibility of the Department of Energy, Mines and Resources to maintain up-to-date data and provide policy advice on the subject to the Government of Canada, energy was a prime concern for EMR during the year.

The price of Canadian oil remained at the $6.50 a barrel agreed to at the First Ministers' Conference in 1974, but there was strong pressure to increase this amount to a level closer to the world price, although agreement to implement this could not be reached at a subsequent First Ministers' Conference in 1975. The price of natural gas for export to the United States, however, was increased from an average of 60 cents to $1 a thousand cubic feet from January 1, 1975.

Another high-profile subject also in the energy field in the latter part of 1974 was the future of the Syncrude project in the Athabasca Oil Sands in Alberta as a result of the withdrawal of one of the original members of the consortium. Eventually, after intensive discussions between industry and federal and provincial governments, an agreement was reached whereby the federal government would share in the huge project to the extent of 15 per cent, with Alberta and Ontario undertaking 10 and 5 per cent of the venture respectively. A Bill was introduced in the House of Commons to authorize the setting up of a crown corporation, Petro-Canada, both to administer the federal government's participation in Syncrude and become involved in other aspects of the petroleum industry such as exploration.

An indication of EMR's involvement in the energy situation is that the budget for the department for the year more than doubled, but more than four-fifths of the total, an amount of $467 million, was accounted for by oil subsidies.

With its responsibility to act as adviser to the Minister of Energy, Mines and Resources on all matters pertaining to the developing, processing and export or import of Canada's mineral resources (other than fuel), the Mineral Development Sector is concerned among other considerations with maintaining federal-provincial relationships in the mineral field. With this objective in view, a Canadian Ministerial Conference on Mineral Policy was set up a year ago. Towards the end of 1974 the first meeting of the Conference was held and mines ministers from both levels of government agreed to joint publication of a report entitled *Towards a Mineral Policy for Canada: Opportunities for Choice*, which sets out possible directions for future Canadian mineral policy. Another

form of joint consultation sustained by the Mineral Development Sector is the National Advisory Committee on the Mining Industry, which brings together federal government and mining industry leaders and consultants: the Committee met on three occasions in 1974.

While the Energy and Mineral Development Sectors of the department are principally concerned with policy development and advice to the Minister in those respective areas, the Science and Technology Sector supports the above sectors through provision of technical data and information, and manages a national earth sciences service program with substantial input in the above. This program is based on the systematic inventory of the Canadian landmass, its mineral and energy resources, physical properties and other phenomena, and its surface features.

The subdivision of the Science and Technology Sector reflects the scope of its involvement: Canada Centre for Mineral and Energy Technology, Geological Survey of Canada, Surveys and Mapping, Earth Physics, Canada Centre for Remote Sensing, Explosives, and Polar Continental Shelf Project. Activities include scientific and technological information, technological development, resource estimation, appraisal of natural hazards and of development on a regional basis, and cooperative logistic support of northern scientific projects. The Science and Technology Sector manages about 80 per cent of EMR's operating budget.

Many of the above units have a long record of providing data and technical information to the public and more specifically to the mining and petroleum industry at large. But the fiscal year 1974-75 saw an ever increasing effort on the part of the sector to also direct its technological activities and geoscientific surveys towards deriving information required for policy development. Consequently the interrelations of units within the sector, and between sectors are ever intensified towards producing a multifaceted and cohesive approach to national problems.

Since early in 1975, the former Mines Branch has been undergoing an indepth reorganization and changed its name to the Canada Centre for Mineral and Energy Technology (CANMET). This name change reflects more accurately the steady broadening of that branch's activities, such as current research needs in the energy field, including oil sands and petroleum technology. Among the research projects undertaken by CANMET that are of particular interest in these days of energy shortages have been several studies related to conservation of energy in industrial use, central heating applications and improved fuel combustion for automobiles.

The diversification in activity direction added to the challenges facing the Geological Survey of Canada (GSC). The systematic survey of the geology of Canada has reached a stage where such activities are focussed more and more in the frontier regions of Canada, both on land and at sea, and this is timely as frontier resources are undergoing development. Yet the need to assess Canada's mineral potential, for policy formulation and for proper management of development, demands a comprehensive overview of the country's resources, the development of reliable assessment methods, and the coordinated efforts of various governmental agencies to provide that overview, all of which made heavy demands on the GSC.

Besides resource inventories, environmental concerns and engineering feasibility studies related to resource or other developments, increasingly tended to divert attention from systematic surveys of the landmass. Thus, studies of terrain sensitivity and regional seismicity, specially in relation to pipeline and other energy developments, monitoring of sea ice and of other features demanding periodic synoptic observations by satellite, the need for proper positioning of survey stations or observational tracks, proper location of observed stata, and for special maps to record and portray the resulting information also made increasing demands on the sector, including the Earth Physics, Remote Sensing, and Surveys and Mapping branches. The large seasonal deployment of departmental field parties in the Arctic, as well as an all round increase in northern activities, augmented the ever larger dependence on the coordinated logistics provided by the Polar Continental Shelf Project. Similarly the Canada Centre for Remote Sensing, originally conceived in the department as a means of providing information for national resource management, saw the scope of its interdepartmental and national cooperative service extended in kind and in volume. Proliferation in types of explosives and in their use, growing public concern for safety and security, were factors increasing the activities of the Explosives Branch in its administration of the Explosives Act. In this the branch was supported by the explosives laboratories located in CANMET.

During the year, EMR, Information Canada and the Macmillan Company of Canada Limited brought together some of the finest work available anywhere in the arts of map making and fine printing with the publication of the fourth edition of the National Atlas of Canada, which has been widely acclaimed. A total of 15,000 copies were sold to libraries, academic and government institutions and private individuals across Canada and in other parts of the world.

In the case of all of the divisions of the Department of Energy, Mines and Resources, the following pages present details of only some of the more significant projects. For those interested in more complete technical detail, reference should be made to the professional reports of each group.

Energy Development Sector

In 1974, and continuing into early 1975, the world energy situation captured the front pages of daily newspapers as well as intensive coverage on radio and TV.

Oil and gas dominated the energy scene in Canada. The decline in available resources worried the federal and provincial governments, and the public at large. No new large oil or gas fields were found in the traditional western resource base and results from exploration in the Territories, the Arctic Islands and the eastern offshore, were below expectations. However, frontier oil and gas finds made to date promise significant new production in the years ahead.

Canadian oil remained at \$6.50 a barrel, a price set at the First Ministers' Conference in March, 1974. Canadians generally pay the same price for oil from coast to coast except for differences in transportation costs and provincial taxes. An import compensation program offsets the high price of imported oil in eastern Canada so that consumers pay the same price allowed for Canadian oil. This program has been largely financed from exports of Canadian oil at world prices.

The price of natural gas has been below the comparable commodity value of other energy forms. The price of natural gas exported to the United States was raised from an average 60 cents per thousand cubic feet to \$1 per thousand cubic feet effective January 1, 1975. In the period reviewed, no large increases were announced for the domestic market, where gas remained underpriced in terms of other fuels.

Exports of oil to the United States have now been reduced. Gas shortages caused by production problems in two northern British Columbia fields resulted in some curtailment of gas exports to the northwest United States.

Western Canadian coal development and production continued to dominate the national scene but Nova Scotia increased production in 1974 for the first time in many years. Sharply higher coal prices and the inability to negotiate long-term contracts with U.S. suppliers were of concern to Ontario Hydro and the Ontario steel mills. The department continued to evaluate coal resource availability and supply capabilities for foreign and domestic markets, with increasing attention devoted to the industrial and utility requirements of central Canada.

Results of some studies on regional electrical interconnections came to a successful conclusion in 1974-75. These included the generation expansion plans on the Churchill River in Labrador and an interconnecting cable between Prince Edward Island and the mainland.

Two important policy statements on uranium and nuclear safeguards were made during the reporting year. On September 5 the government specified the need for a complete uranium resource appraisal, outlined terms on which Canadian uranium would be made available to meet future domestic nuclear requirements, and set out regulations under which uranium would be exported. On December 20 the Minister in the House of Commons reviewed the status of Canada's nuclear industry and outlined more stringent safeguards for all exports of nuclear technology, facilities and material.

Drilling activity on the Scotian Shelf and the Grand Banks on Canada's east coast decreased during the year. However, two significant discoveries of natural gas were made off the Labrador coast.

Moving from this brief summary of highlights for the year under review, the balance of this section will deal in more detail with developments affecting Canada's future in oil, gas, coal, hydro and nuclear power.

The Energy Development Sector administered the Oil Import Compensation Program until November 1, 1974, when the responsibility passed to the Energy Supplies Allocation Board. During the sector's stewardship of the program, provisional compensation payments totalling $625 million were made to cushion the impact on Canadian consumers of sharply higher overseas oil prices. The experience of putting in place a program of this magnitude at short notice was a valuable one. However, it was gained at some expense in terms of policy development in other oil and gas areas. Transfer of this responsibility enabled staff to be concentrated more fully on policy matters.

During 1974 the National Energy Board held public hearings on the export of crude oil, which included the supply and demand situation in Canada. From these hearings the board made several recommendations to the government, one of which was the reduction of the amount of exports to the United States. This reduction was announced by the Minister on November 22, 1974. At that time he stated that exports would be reduced to a maximum of 800,000 barrels a day effective January 1, 1975. The board will identify the volume of allowable oil exports for a period of at least one year, but annual levels will be adjusted to account for immediate supply and demand factors by issuing monthly export licenses.

The Minister outlined in his statement that there would be an inevitable decline in producibility of indigenous crude oil starting in 1975 and continuing in the 1980's, when frontier oil and larger quantities of oil sands output are expected to become available. Based on the current supply and demand trends the board forecast a deficiency in supply to the domestic market served by Canadian oil in early 1982. This deficiency would reach 200,000 barrels a day by late 1983.

A similar study on the supply and demand situation for natural gas was conducted during 1974 and 1975 with the hearings being completed in February, 1975. The report was to be released later in 1975 but indications were that the situation for natural gas supply paralleled crude oil. The traditional western prairie sources were being depleted faster than new discoveries were made. Shortages of natural gas might develop in Canada before frontier discoveries could fill the gap.

In the spring of 1974 a group of specialists was assembled by the federal government to make an assessment of the application that had been submitted to the Department of Indian Affairs and Northern Development and the National Energy Board proposing the construction and operation of a natural gas pipeline from Alaska and the Mackenzie Delta to southern markets. The applications had been filed on March 21, 1974, by the Canadian Arctic Gas Pipeline Limited.

Mr. Justice Thomas R. Berger was appointed to conduct the inquiry into the social, environmental and economic impact regionally of the proposed pipeline. Mr. Berger held preliminary hearings in the summer of 1974 at Yellowknife, Inuvik, and Whitehorse. Formal hearings opened in Yellowknife on March 3, 1975. The National Energy Board hearings will start later in the year.

A second application has also been filed with the federal government by Foothills Pipeline Limited for a pipeline project that would transport Canadian gas from the Mackenzie Delta and the Beaufort Sea to points of connection with present gas pipelines in the provinces.

Progress on the Polar Gas Project included research and engineering feasibility studies on the proposed natural gas pipeline from the Arctic Islands to southern markets. The route, spanning more than 3,000 miles, would follow the west or east side of Hudson Bay.

In the fall of 1974 the future development of Canada's oil sands was shaken by the withdrawal of one partner from the Syncrude consortium, engaged in construction of the country's second oil sands plant near Fort McMurray. To ensure that this nationally important endeavor would proceed, government-industry negotiations led to the formation of a new partnership in which the federal government assumed a 15 per cent share, Alberta 10 per cent and Ontario 5 per cent. Private industry is responsible for 70 per cent. The project is slated for completion in 1979, with a production capacity of 125,000 barrels a day.

Canada has a modern refining industry which, by the end of the 1974-75 fiscal year, had a capacity in excess of two million barrels per day of crude oil. Construction of major new refineries in Newfoundland and Alberta was completed and a number of other refineries were being expanded.

The Department of Energy, Mines and Resources has been involved in many international discussions in the past year, including a number with the United States, on the future supply of crude oil and natural gas from Canadian sources. Discussions have also centred on the use of oil tankers on the west coast and the potential environmental problems for Canada in the event of a spill from a tanker carrying oil from Alaska to the United States.

Representatives from the department have participated in all the meetings of the International Energy Agency since its inception in 1974 after the worldwide oil embargo by the Organization of Petroleum Exporting Countries (OPEC).

At the end of the reporting period the department was preparing for the First Ministers' Conference on Energy which was to be held in early April.

The department is carrying out an analysis of coal supply and demand in relation to the higher prices now charged by the coal suppliers, especially those by U.S. coal companies that provide the coal for Ontario Hydro and the Ontario steel mills. These prices have, in many instances, doubled since 1973.

The federal government is concerned with the availability of future coal supplies for Ontario and studies are continuing on the feasibility of using western Canadian thermal and metallurgical coal.

Higher coal prices boosted the Nova Scotia coal industry, which stepped up production in 1974, finally checking a trend in recent years to lower output. Outlook for near-term productivity and profit has improved as the Lingan mine nears full operation.

The department continues to supervise the federal government's responsibility in the national coal inventory now under way including coal resource studies being carried out in Nova Scotia and Saskatchewan for which the federal government does the data compilation.

Developments on coal gasification are continually monitored. In 1974 a visit to West Germany, United Kingdom and Spain was organized for representatives from the federal and provincial governments and industry to examine coal conversion facilities, especially coal gasification.

Calgary attracted in 1974 the largest number of delegates ever to attend a Canadian Conference on Coal. Co-sponsored annually by the department, the conference will be held in Vancouver in 1975 and Ottawa in 1976.

Several activities related to regional electrical interconnections took place during the year. In cooperation with other federal departments and provincial authorities a detailed evaluation was made of the economic and technical aspects of developing hydroelectric energy on the lower Churchill River at Gull Island, Labrador, to meet the needs of the island of Newfoundland. After comparison of this project with alternative generation expansion plans it was concluded that the Gull Island project was the most economical source and an offer was made of financial assistance through federal loans for 50 per cent of the transmission cost to a total of $343 million.

After more than a year of participation in studies with Prince Edward Island, approval was given for federal assistance for an interconnecting cable to tie the P.E.I. electrical system to the mainland. This in the long term will reduce the dependence on oil fuel and allow lower cost purchase of electricity from the mainland systems. A loan of up to $9 million through the department's regional interconnection program has been provided in addition to a grant of $18 million from the Department of Regional Economic Expansion.

Discussions took place during the year with Manitoba Hydro on the criteria for extension of the agreement under which Canada constructed the first stage of the Nelson River high voltage direct current transmission system. This first section is now operational with a design capacity of 1,060 megawatts over a 560 mile distance. No mutually acceptable basis for supplementary agreement on extensions to the system has been reached, although Manitoba Hydro has purchased equipment to extend the capacity of the system to 3,420 megawatts.

An agreement was reached with the Canadian Electrical Association to provide a federal contribution of up to $425,000 for a research and development program. Electric utility members of the association have contributed approximately $1 million to this joint program, which is expected to expand substantially in scope over the next five years. Initial contracts for research work have been committed.

A review was completed in September, 1974, of the prospects for tidal power development in the Bay of Fundy. A reassessment had been made of a study completed in 1969 when it was concluded that at that time, tidal power was not an economically attractive option. The review recommended further studies in four specific areas and this recommendation for additional work at a cost of $3 million has been accepted by the governments of New Brunswick and Nova Scotia as a joint federal-provincial program over a two-year period.

The department has participated over a three-year period in the Lake Winnipeg, Churchill, Nelson River Study Board which has evaluated the environmental and social impact of the hydro development in northern Manitoba. This work is nearing completion and the report of the board will be issued during 1975.

The department played an important role in preparation of the two statements on uranium and nuclear policy announced in the latter part of 1974.

The uranium policy statement made on September 5 ensures that sufficient uranium will be available for Canadian use with utilities contracting for a minimum of 15 years supply for each reactor in service or committed for service. This will ensure that there will be sufficient domestic production capacity to meet these demands.

Export contracts, which must be approved by the Atomic Energy Control Board, will be limited under this policy to a maximum of 10 years with a contingent approval possible for an additional five years.

On December 20 the Minister reviewed the status of the Canadian nuclear industry and outlined the provisions that will be required in every safeguards arrangement. These provisions, which will be administered by the International Atomic Energy Agency or through appropriate alternative procedures, will meet the requirements of the Treaty on the Non-Proliferation of Nuclear Weapons. Contained in the safeguards arrangements will be the binding assurances that any of the Canadian supplied nuclear material, equipment and technology will not be used to produce a nuclear explosive device, whether this is stated to be for peaceful purposes or not.

Atomic Energy of Canada Limited was given encouragement and permission from the government to pursue overseas sales for the CANDU reactor with the stipulation that, as much as possible, the high technology components and services should come from Canada.

The Minister's statement also reaffirmed the position of the government towards any uranium enrichment development. Each case will be reviewed on its own merit but would only be allowed to proceed if it could be proved that it would be for the overall benefit of the country.

With the upturn in the uranium market being favorable to the producing industry several contracts were negotiated and announced. Many Canadian producers now have plans for expansion to meet the growing demand and one company is carrying out a leaching in situ experiment.

Department officials continued to participate in interdepartmental discussions, and also with the New Brunswick government, on loans to cover half of the cost of the first nuclear power plant to be built in the Maritimes. At the end of the reporting period negotiations were almost completed.

The department participated in a study on the potential application of peaceful nuclear explosions as background information for the Department of External Affairs on the Non-Proliferation Treaty review conference to be held in 1975. The department has also had considerable input in the development of research and development policies and on related nuclear work with the International Energy Agency and the OECD Nuclear Energy Agency.

Resource Management and Conservation Branch

The summer of 1974 saw two significant hydrocarbon discoveries off Canada's east coast, one of the offshore regions administered by the Resource Management and Conservation Branch. Both finds were gas, and were made in the relatively unexplored "iceberg alley" off Labrador. One discovery confirmed the results of initial indications in the Bjarni H-81 well drilled in 1973, while the second success was in the new Gudrid H-55 test, 80 miles to the southeast. Operations were carried out by the dynamically-positioned drill-ship "Pelican", which has been specially designed for a quick move off a well-site in case of an approaching iceberg. Drilling at the Gudrid location began on July 12, and after the well had been successfully tested, the drill-ship moved to the Bjarni site to complete the testing of this well before leaving the Labrador Sea on October 25.

Drilling activity on the Scotian Shelf south of Nova Scotia decreased during the reporting year as one of two semi-submersibles working the area departed for South America in late 1974. This unit had been active off the east coast since 1970. The second drilling unit moved to the Bay of Fundy where a well was started in early March.

One semi-submersible unit working on the Grand Banks left in January, 1975, and is now drilling in the Mediterranean Sea off Spain. The reduction in the number of drilling units on the Scotian Shelf and Grand Banks is attributable to lack of positive results in these areas to date. Such is not the case off Labrador. As the result of the two promising discoveries made in the Labrador Sea, the only three drilling units in the world that are capable of working in these deep, iceberg-infested waters are expected to be operating there during the summer of 1975.

Two wells were drilled in Hudson Bay by the ice-strengthened semi-submersible *Pentagone 82* during the summer of 1974. Both wells were plugged and abandoned, as was the Walrus A-71 which had been suspended in 1969. There will be seismic activity in the Bay in 1975 but no drilling is anticipated.

Exploratory drilling expenditures during 1974 totalled $65 million and $13 million was spent on seismic and other geophysical surveys, representing a small reduction from 1973. Twenty thousand miles of seismic work was carried out off the east coast and 5,500 miles in Hudson Bay. There was no significant activity off the west coast.

Work has been progressing on new drilling regulations for both offshore and inland areas. Joint industry-government discussions have been held to review technical content, and the regulations are now in the final drafting stage.

A first draft of new production regulations had been completed and is being reviewed with other departments, primarily Indian Affairs and Northern Development. Following this preliminary review, industry will be given an opportunity to comment on the regulations before they are promulgated.

No Canada Oil and Gas Permits were issued during the fiscal year 1974-75 as the issuance of permits was suspended March 21, 1972. Five hundred permits comprising 39 million acres were returned to the Crown during the year, including 384 deep water permits covering 30 million acres off the Grand Banks and Labrador Shelf. As of March 31, 1975, the branch administered 3,979 permits covering 287 million acres, of which 85 per cent was off the east coast, the region of the greatest exploration activity.

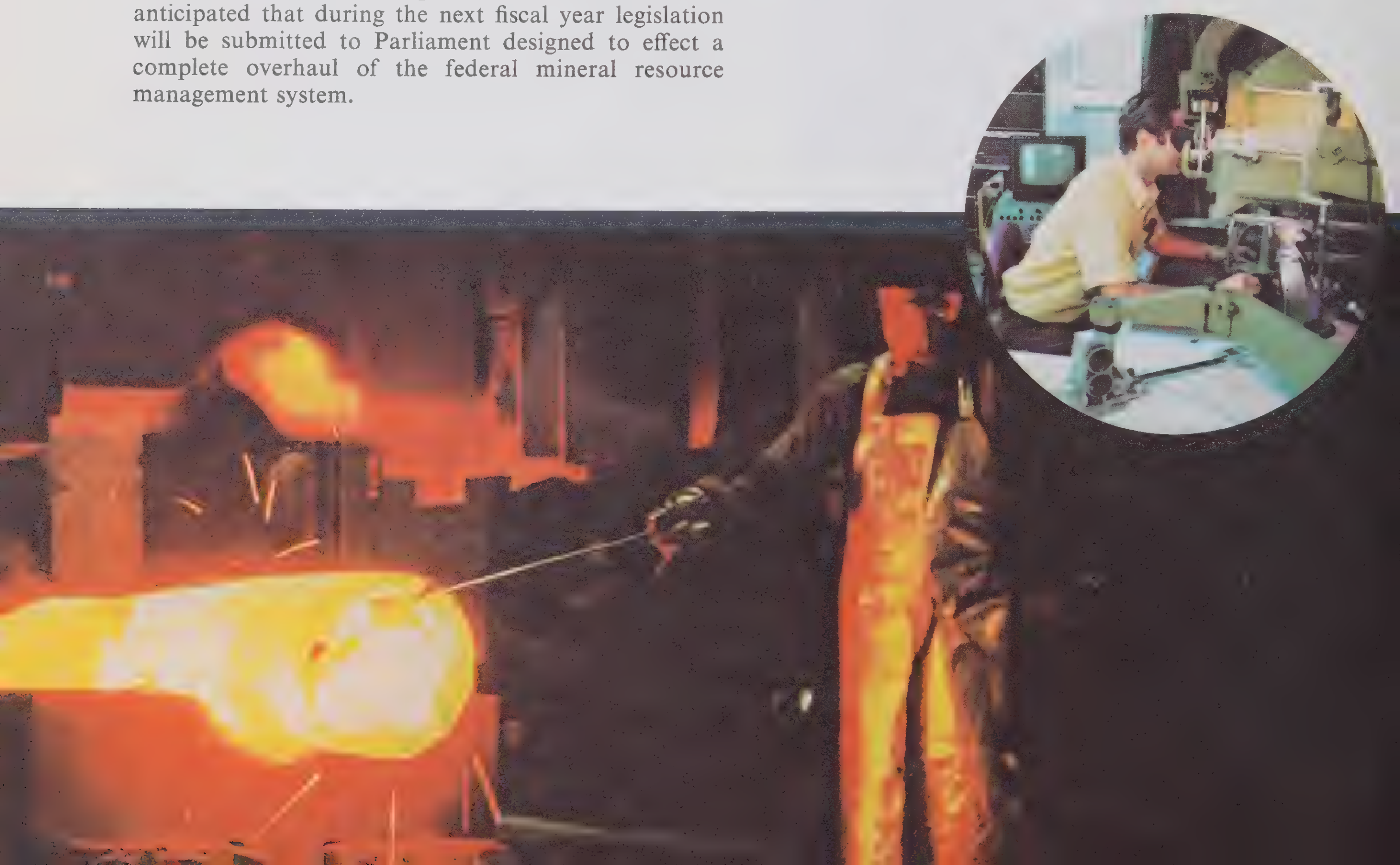
Revenue from "offshore lands" totalled about $401,000, a decrease of 44 per cent from 1973-74. Revenue from federal leases in the provinces was $759,000, largely from production royalties. This constituted an increase of 72 per cent over 1973-74.

During the year, work has proceeded on a comprehensive review of the Canada Oil and Gas Regulations governing administration of oil and gas rights on federal lands outside provincial boundaries. It is anticipated that during the next fiscal year legislation will be submitted to Parliament designed to effect a complete overhaul of the federal mineral resource management system.

The branch continued to provide departmental representation to the Third Law of the Sea Conference, the first substantive session of which was held at Caracas, Venezuela, in July-August, 1974. The issues of primary importance to the department at the conference include, firstly, the definition of the seaward limit of coastal jurisdiction over seabed mineral resources and, secondly, the nature of the international regime and the administrative machinery to govern seabed resource activities beyond this limit.

As regards the first issue, Canada is negotiating for confirmation of her sovereign rights to mineral resources over the whole of her continental margin, including that significant portion extending beyond 200 nautical miles, the jurisdictional limit supported by the majority of States. Concerning the second issue, Canada is striving to seek a formula for an international seabed regime that will be acceptable to the majority of States and yet meet her own requirements, that is, allow access to seabed mining activities by Canadian companies, and at the same time provide safeguards against the possible adverse effects of seabed mining on domestic mineral development.

The second session of the Conference opened in Geneva in mid-March 1975 and was to continue until early May.



Energy Conservation

The Office of Energy Conservation has been in existence a little over a year. Focussing mainly on the demand side, its purpose is to identify ways to conserve energy in Canada by reducing rates of energy consumption and by improving the efficiency with which energy is consumed in specific uses.

One of the principal tasks carried out by the Office of Energy Conservation during the year was the development of a recommended national policy on energy conservation which the Minister presented to the House of Commons on February 6, 1975. Two important phases of the policy were inaugurated and under way before the end of the fiscal year: the federal government in-house conservation program and the public information and advertising campaign. Under the former, a departmental conservation committee was formed and made recommendations particularly in the areas of more efficient use of public buildings, economies in the use of paper and more economical operation of government vehicles. The advertising campaign began with full-page advertisements in daily newspapers across the country, backed up by TV and radio spots. Work also proceeded on publications aimed at special interest groups—homeowners, automobile drivers and high school students.

The Mineral Development Sector

The Mineral Development Sector is charged with developing federal policies for Canada's mineral resources with the exception of mineral fuels. To achieve this objective, sector staff carries out detailed analyses of problems and opportunities related to Canadian minerals. On a day-to-day basis the sector serves as mineral economic adviser to the Minister of Energy, Mines and Resources, and to federal and provincial departments and agencies concerned with mineral development. Sector studies and activities embrace broad mineral issues as well as specific mineral commodity problems and opportunities. The sector provides alternate viewpoints on how specific policies—governing trade, taxation, or regional development, for example—might enhance or impede the contribution of the mineral sector to the overall development of Canada.

The sector is organized into four economic-technical divisions with a supporting Information Systems Division. The functions of each division and some of its major activities are briefly outlined below.

Any federal agency concerned with mineral development maintains vital ties with its counterpart departments and officials in the provinces across Canada, and with the Department of Indian and Northern Affairs, which has authority over minerals in the Yukon and Northwest Territories.

Over the years, the federal-provincial relationship has been sustained by federal representation at the annual Provincial Mines Ministers Conference, and was recently strengthened by the creation in 1973 of the Canadian Ministerial Conference on Mineral Policy (CMCMP). The Conference provides a forum for consultations on issues that affect all regions and provinces. Consultations take place at the levels of both Ministers and their Deputies.

At the first meeting of the Conference in late 1974, federal and provincial mines ministers reviewed and agreed to joint publication of a document proposing directions for Canadian mineral policy. Entitled *Towards a Mineral Policy for Canada: Opportunities for Choice*, the federal-provincial document was issued to the public early in 1975. It follows an earlier publication that defined mineral policy objectives. *Towards a Mineral Policy* identifies directions future policy strategies could take, such as diversifying regional and national economies through further processing and fabrication of minerals. The challenge is to increase mineral processing and financial returns while ensuring that other objectives are met, among them resource sufficiency for domestic needs, environmental quality, social stability, domestic control, and international obligations.

In another forum, the National Advisory Committee on the Mining Industry (NACOMI), the Minister of EMR meets with representatives from industry. Membership in NACOMI consists of leaders of major Canadian mining companies and other prominent consultants who are asked to contribute their specialized knowledge and advice. During 1974, NACOMI met on three occasions to exchange views on federal mineral policy proposals.

In relation to evolving a national mineral policy, studies were begun in the sector on major mineral commodities and other key factors related to mineral development in Canada. These studies will form the basis for the next step in policy formulation—identifying appropriate strategies to attain the mineral policy objectives already defined by the federal government and the provinces.

Mining Industry Financial and Corporate Analysis

In 1974, a re-organization of responsibilities within the sector resulted in the creation of the Mining Industry Financial and Corporate Analysis Division. Its sphere of interest includes the existing patterns of sharing the revenues generated by the mining industry; the effects on the industry of new mining regulations and taxation provisions; the economic viability of new mining ventures, especially where some form of direct government aid may be involved; and the extent to which the mining industry is owned and controlled by Canadian interests. The division will also study significant issues in the fields of mining finance and investment in relation to the development and implementation of mineral policies.

As required, division staff will give advice and assistance to the Department of Finance in the area of fiscal policy affecting the mining industry; to Revenue Canada in administration of the Income Tax Act as it applies to the mining; and to the Foreign Investment Review Agency. (FIRA screens applications for new industrial acquisitions by non-Canadian interests.) On request the division lends its technical expertise to the provinces in the review and analysis of new mining tax and royalty systems.

Minerals and Metals

The Minerals and Metals Division analyzes current trends in all phases of mineral development, from exploration through to production, processing and marketing. On this knowledge base, supplemented by specific commodity studies, advice is provided to the Minister and to other government departments. Officers of the division also represent EMR in interdepartmental and international committees relating to Canada's trade commitments in minerals and metals.

On the heels of the energy crisis of 1973-74, considerable attention in international forums focussed on minerals supply and demand. Existing commodity producer groups (copper, iron ore) improved their control over prices and others came into being (bauxite, mercury).

In April, 1974, a special session of the United Nations General Assembly was based on the theme "Raw Materials and Development". The Canadian delegation reiterated Canada's policy preference for commodity arrangements that involve both producers and consumers. In keeping with this policy Canada attended, as an observer only, several meetings of producer associations including those for iron ore and copper.

In the current round of multilateral negotiations under the General Agreement on Tariffs and Trade (GATT), the issue of further processing is of special importance to Canada. Now trade barriers tend to be substantially higher for processed than for unprocessed raw materials, including mineral products. The GATT negotiations call for a reduction of tariff barriers and a removal of non-tariff obstacles to trade. Hence the negotiations offer an important opportunity for Canada to obtain freer access to foreign markets for processed mineral exports. During 1974-75, officers from the Mineral Development Sector represented EMR in interdepartmental work preceding GATT meetings.

The results of sector analyses of the trends in mineral production and trade are published in a monthly review of the industry, in the annual Canadian Mineral Survey, and in more detail in the Canadian Minerals Yearbook. Of particular interest in 1974 were the sharp changes in demand and price for many minerals, especially for copper, potash and sulphur. Copper prices declined drastically toward the end of 1974, after having reached an all-time high in mid-year.

Potash demand surged with the rapid increase in demand for fertilizers throughout the world. The turnaround in the sulphur market was particularly dramatic as the glut of the past three or more years was replaced by a shortage of supply in 1974. This supply shortage was again due to worldwide fertilizer demand as well as transportation difficulties in moving the supplies from Canada's large Prairie stockpiles (derived as a by-product of sour natural gas production) to world markets. The Canadian transportation problem emphasized Canada's influence as the world's largest supplier of sulphur.

Resources and Development

The Resources and Development Division has broad responsibility for planning mineral development programs in conjunction with provincial and other federal government departments. The division is also concerned with determining the magnitude of Canada's mineral resource base.

Regions of the country are not equally endowed with minerals, and the pattern and pace of economic development varies amongst regions. To identify regional development problems and opportunities related to mineral reserves, federal and provincial governments have undertaken a number of joint cost-shared programs.

At the federal level, the planning and management of such development work is generally undertaken by the division in conjunction with the Department of Regional Economic Expansion. Since these programs were begun in 1970, projects have been carried out in several provinces, with greatest attention to regions in need of a broader economic base and areas where there are opportunities for expansion based on mineral reserves.

Program costs have varied from $500,000 to over $11 million, and are implemented over two- to six-year periods. In 1974, new federal-provincial mineral agreements were undertaken with Nova Scotia, Alberta and Saskatchewan. Other programs for Manitoba, Quebec, New Brunswick, Ontario and British Columbia were under negotation or in the planning stages. All projects in the Newfoundland program, begun in 1971 and funded equally by EMR and DREE, were completed.

Because of Newfoundland's late entry into Confederation, the province has had considerable catching up to do in geological mapping. Mineral occurrence maps produced under the program have helped to fill the gap, and mineral inventory work will be continued. Other wide-reaching results include reform of the provincial land tenure system where long-term concessions had been preventing effective exploration. Also, an inquiry was held to investigate provincial mining taxation. Increasing exploration and development activity in the province attests to the success of this relatively modest program.

With a view to broadening the industrial base of the Atlantic provinces, investigations were carried out on the feasibility of zinc processing plants in New Brunswick and Newfoundland, based on ore resources from local and northern deposits. The possibility of establishing a zinc smelter in the Yukon is also undergoing extensive study.

The division provided extensive economic analyses on the feasibility of the recently established Strathcona Sound lead-zinc mine on the northern tip of Baffin Island. This is the first mine in the Canadian Arctic Islands and is a joint venture between the Government of Canada, which owns an 18 per cent interest, and private industry. Studies are also being carried out on a company proposal to establish a lead-zinc mine on Little Cornwallis Island.

The Mineral Area Planning Study (MAPS), initiated in 1972, was completed and readied for publication in late 1975. The study provides a framework for decisions on regional mineral development by examining production of key mineral commodities in relation to future domestic needs and foreign demand.

The division compiled an interim manual of mineral resource and reserve definitions for use within EMR and for circulation to provincial governments, as well as to other appropriate national and international agencies. The aim is to ensure that all those engaged in estimating and describing mineral resources use a standard technical language.

Mineral Economics

The Mineral Economics Division analyzes and recommends alternative policies for minerals. This entails identifying mineral industry opportunities and problems, and economic and social effects that may arise from mineral development.

The division is concerned with three main subject areas: mineral-based industries in relation to Canada's total economy and export markets; economic development, including the international role of minerals; and the social impact of mineral development.

During 1974-75, projects included measurement of the impact of Canada's mineral industry on the economy as a whole. An economic model developed by Statistics Canada was used to provide a detailed picture of the mineral industry within the economy as both a purchaser of goods, and as a supplier of raw materials to other industries.

Using CANDIDE, the econometric model of the total economy developed by the Economic Council of Canada, work continued on the analysis of mining industry investment. One project is investigating the benefits to Canada that could be derived from further processing of particular minerals, or from investing in different segments of the mineral industry. The study will examine the structure of individual commodity systems, that is, the interrelationships between the series of activities bringing a particular mineral from mine to market, and the relationship of these activities to other sectors of the economy.

The division is also concerned with the social impact of the mineral industry in Canada. Areas of investigation include pollution and land-use problems, as well as labor shortage and turnover in the mining industry. An in-depth survey of 20 representative mining communities across the country led to the conclusion that the design of any new mining community must take into account human, social and cultural values along with financial, economic and technological objectives if manpower instability is to be reduced. The study also identified the possible changes which, if implemented, would improve the quality of life in existing mining communities.

A preliminary study on minerals and the environment is under way, focussing on such issues as: the environmental consequences resulting from mineral activities; health and safety within the working environment; mineral conservation; and the economics of pollution control.

The division also maintains close contact with the academic community, bringing together research related to mineral economics. In this realm, the Centre for Resource Studies, sponsored jointly by the Mining Association of Canada and EMR and administered by Queen's University, began its first year of operation. Its purpose is to provide a nucleus for independent, high calibre economic research on important issues of mineral resource development and mineral policy. In 1974-75, a basic research program entitled "Impact of the Mineral Industry" was initiated, and at the end of the fiscal year the first applications and research proposals were being discussed.

In addition, the division administers the sector's research agreements. In 1974-75, $31,568 in grants were awarded to researchers in various disciplines at universities across Canada, thus increasing the academic community's involvement in mineral resource problems and issues.

Information Systems

The Information Systems Division operates a statistical group, a resource economics library, a technical records centre, and the National Mineral Inventory. The division centralizes the collection, storage, manipulation, retrieval and dissemination of mineral industry information that has multiple applications and frequent use. Computerized data files, using the facilities of the department's Computer Science Centre, provide the link through which statistical and descriptive data are provided to management and researchers. In addition to serving the sector and department, the division provides information to other federal departments, the provinces, industry and the public.

Science and Technology Sector
Surveys and Mapping Branch

Providing up to date map information and accurate survey measurements for public use, particularly in the Arctic and northern Canada where the growing importance of exploration and development of natural resources requires these services, is the important responsibility of the Surveys and Mapping Branch. During the fiscal year 1974-75, the branch investigated several methods for facilitating this task.

The major products of the Surveys and Mapping Branch are accurate topographic maps, aerial photographs and data from a national network of survey control points precisely established and maintained by government geodesists. These are basic tools for the development of Canada's resources and have always been essential for many industrial, scientific, educational, legal, engineering and tourist-industry purposes.

Total budget for the Surveys and Mapping Branch during 1974-75 was $20,940,000. Of that $6,016,000 was spent on control and legal surveys, $6,161,000 on mapping services, and $3,690,000 on distribution of technical information, with $2,100,000 being recovered through the sale of maps and air photographs. A sum of $70,000 was allocated for feasibility studies and contract management of external aid projects for the Canadian International Development Agency (CIDA) and the balance of the budget went for administration.

Inertial surveying equipment with potential to change the face of surveying in Canada in the near future was acquired for assessment early in 1975 by the Geodetic Survey of Canada—the agency in charge of establishing horizontal control (latitude and longitude) and vertical control (exact height above sea level) of selected points across the nation. The equipment, an outcome of the United States space program, is capable of providing, at the push of a button, precise figures of latitude, longitude and elevation of any point. A survey line can be run at the speed of the vehicle carrying the equipment. Such equipment will save the time now needed for traditional measuring by angles and lengths in many areas of Canada.

Over the past few years, geodesists have found that there are definite distortions in the national network of horizontal control because measurements made by the new high-accuracy instruments do not conform with data from older surveys. To correct this, a complete readjustment of the national network has become necessary and data gathering for this task began in 1974 with the establishment of 52 Doppler Stations in the Arctic, Quebec and Greenland. The method of establishing horizontal control points on the ground by measuring the Doppler frequency shift of satellites whose exact positions are known at all times is now being used extensively for geodetic work. The Doppler stations will act as an anchoring framework for the mathematical adjustment of existing coordinates of control because the satellites pass over the whole country, providing a uniform surveying reference for Canada and a system that is modern and accurate and to which other geodetic control points can be related for correction. The Doppler survey of Canada, to be completed in two years, is accompanied by similar programs in the United States and Mexico. All will help develop a more uniform survey datum for the whole of North America.

The readjustment program also includes extra surveying to strengthen weak parts of the network and resurveying in regions where older surveys exist, followed by computer readjustment of all data for homogeneity of the system. During 1974-75, the branch extended a first-order traverse from Yarmouth to Liverpool, N.S., and from Stewart, B.C. northward to the Alaska highway near Watson Lake to complete surveying in these areas. This is the second year the branch has used a first-order traverse which involves measuring the distance between two points by using electronic distance-measuring devices and angular measurements—a departure from the time-consuming method of calculating distance by triangulation. Another surveying operation in the Arctic Islands, Keewatin District, N.W.T., and northern Quebec resulted in 2,870 miles of second-order traversing and the establishment of 202 new monumented stations to be used as data in production of maps at 1:50,000. The branch also provided a special survey of northern Manitoba to prepare the way for provincial development in the region.

Accurate and adequate local surveying networks are necessary for coordinated and orderly growth of Canada's urban areas. During 1974, in response to this need, the branch commenced a program of cooperation with municipalities in densifying the local survey control networks. The biggest project provided more horizontal control points around Kitchener–Waterloo, Ont. following a request from the municipality. Another project supplied precise levelling (height above sea level figures) for Winnipeg that will be of special use in urban engineering.

Under the metrication program the branch drew 87 new topographic maps with metric contours. Metrication will continue until all maps of the National Topographic System have height information in metres. The change-over will be slow but steady because of the long revision cycle for most Arctic areas (up to 25 years) and because about 10,000 sheets are now published with foot contours. The branch hopes to complete the changeover by 1990.

Photographs from satellites have proven to be an important quick updating tool for mapping and the branch continued to develop this potential in 1974-75. ERTS imagery is particularly useful for wilderness areas where exploration and development are bringing fast and important changes. During the year the photography was used to locate and plot such features as new roads, pipelines, power transmission lines and man-made lakes behind new dams and to correct features previously shown as islands in the Arctic which were in fact areas of sea ice. Specially flown satellite photography was also obtained from Skylab's unique metric cameras over a few areas of southern Canada in the spring of 1974. The branch tested this experimental imagery for use in supplementation of horizontal control for 1:250,000 mapping and provisional 1:50,000 mapping. This photography can be enlarged several times without significant loss of detail because of the relatively high resolution.

During 1974 the branch published the first cadastral photomaps for federal lands. This was an experimental project in Peigan Indian Reserve in Alberta. Further cadastral photomaps are now in preparation for eight more Indian Reserves in five provinces and for the St. Lawrence Islands National Park. Cadastral photomaps help administrators of such government lands as Indian Reserves and National Parks to identify lots, land parcels, political boundaries and buildings in their territory because these cadastral items are superimposed on aerial photographs that also show such landmarks as trees, hedges, fields, roads and waterways.

Surveyors, engaged by the Surveyor General, completed surveys for eight large new Indian Reserves around Big Trout Lake in northern Ontario in time for the June, 1974, meeting between the Indians and the Ontario government.

In 1974, Parliament passed the Alberta-British Columbia Boundary Act which provides for the creation of a boundary commission. This Commission has authority to resurvey the mountain portions of the boundary between the two provinces, to maintain the boundary and to deal with any problems relating to the whole boundary without further reference to Parliament.

The International Boundary Commission built new monuments for 74 stations along the 141st meridian between Canada and Alaska. The new marks, made up of copper clad steel rods drilled three to four feet into rock or permafrost with a bronze tablet on top, replace the old stone cairns, many of which have been destroyed. Such permanent marks are necessary because the stations are used more and more as reference points by those doing surveys for resource development in the area. The Commission also inspected 113 monuments along the boundary between Quebec and the United States west of Lake Champlain on the 45th parallel, upgrading surveys and replacing 27 monuments with permanent markers going five feet into the ground. Rights to the Lambert Tower, a light-weight tower for precise traversing and triangulation invented and developed by the Commission, were given to a private firm and put into commercial production in 1974.

The publication of a bound version of the fourth edition of the National Atlas of Canada by the Macmillan Company of Canada Limited in association with the Department of Energy, Mines and Resources and Information Canada in 1974 marked a first as far as cooperative publishing ventures between the government and private firms goes. The government provided the geographic research, cartographic design and printing plates while the private firm accepted the responsibility of printing and marketing the product. The 15,000 copies published have been distributed across Canada and abroad. Production of the National Atlas is a permanent branch project with each edition providing an up to date graphic summary of Canada's physical setting, human geography, resources and economy that depicts the nation's growth. Plans for the fifth edition were launched in October 1974 with a meeting of the Advisory Committee on the National Atlas of Canada attended by 17 geographers and cartographers from universities and government agencies across Canada.

Safety in airport areas used by both visual and instrument flight traffic is the objective behind the design of a new series of detailed terminal area aeronautical charts produced by the branch in 1974-75 for pilots navigating by visual flight rules. The additional detail deals with air traffic control of visual flying, and will allow the pilot to safely navigate areas of congested traffic. The Vancouver chart, first of the series of 10 at a scale of 1:250,000, was available in March, 1975, and was soon followed by charts for Toronto, Winnipeg and Montreal.

The Canadian Permanent Committee on Geographical Names published new editions of the Alberta and Ontario volumes of the Gazetteer of Canada series and completed verification of names now on record and collection of new ones for a book on geographical names of Nova Scotia. This book will be similar to those already published for Prince Edward Island and New Brunswick. Information is being gathered for books on geographical names of the Northwest Territories and names of under sea features.

The hook-up of the Geological Survey of Canada with the Surveys and Mapping Branch's automated cartography system in 1974 now allows the branch to produce geological maps by computer-assisted cartography. This connection is the first with an agency outside the Surveys and Mapping Branch. Plans for other hook-up stations include one with the Ontario government to enable the exchange of mapping information between federal and provincial map makers in a matter of seconds.

Converting maps from one projection (the mathematical representation of the curved earth as a flat map) to another is the topic of a new branch publication "An Integrated Approach to Map Projections and Plane Coordinates" of special application to computer programming.

Surveys and Mapping Branch products in 1974-75 included a new edition of the Yukon and Northwest Territories map at a scale of 1:4,000,000 and new editions in English and French of the Map of the World at 1:35,000,000 scale. As part of its program of cartographic service to other government agencies, the branch also printed a set of 27 territorial electoral maps for the councils of the Yukon and Northwest Territories, a set of 55 maps for the National Museum of Canada and a revision of the Highways of Canada map for the Government of Canada Travel Bureau.

During 1974-75, 3,777 maps were printed in 9,525,953 copies. Of these, 1,040 were of the branch's own national topographical map series and included 155 new multicolor maps and 453 revisions, 295 monochromes and 137 photomaps. In addition, 772 maps of the series were reprinted — an increase of 90 per cent over last year — to keep the branch's inventory of 10,293 map items and 18 million maps in stock complete and available to the public. During 1974-75, about 3,000,000 maps were sold through the Canada Map Office. The National Air Photo Library answered 14,093 requests for aerial photography.

In 1974-75, the National Air Photo Library Reproduction Centre began a program to produce summer and winter photomaps for the whole of Canada from ERTS photographs. By the end of April, 1975, mosaics showing summer and winter coverage of Manitoba and summer coverage of the Arctic were available. An entire coverage of Canada in 12 blocks at 1:2,500,000 and National Topographical Series map format at 1:1,000,000 was completed soon afterwards. The maps show names of major features and cities and the Universal Transverse Grid and are based on the best ERTS photographs taken over the past four years. They are of special use to oil companies, geologists and environmentalists.

Calgary is the site of the National Air Photo Library's first regional office for aerial photograph distribution, opened in March, 1975. The office has a microfilmed aerial photographic coverage of Alberta and microfiche cards from which the public can order the photographs. The office's present coverage will probably be expanded to include photography of all Canada.

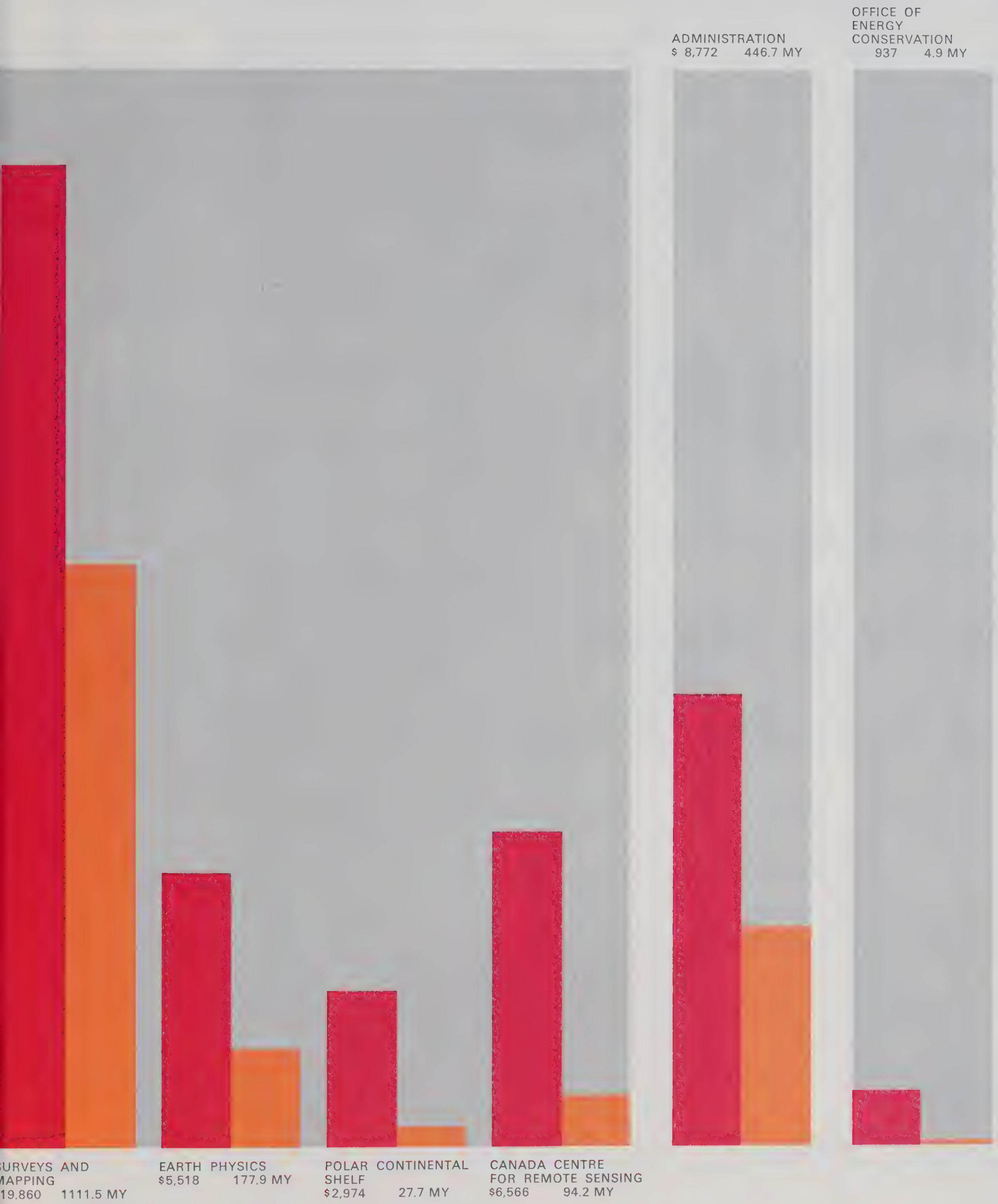
In another decentralizing move, the Maritime Resources Management Service (M.R.M.S.) received 201 rolls of aerial photography covering New Brunswick, Nova Scotia and Prince Edward Island from the National Air Photo Library following the committee's decision to open a centre of distribution for these photographs in Amherst, N.S. M.R.M.S. will now take responsibility for future aerial coverage of the maritime area along with all reproduction and distribution of aerial coverage of the area done by the federal government. The federal government also loaned M.R.M.S. equipment for microfilm and microfiche viewing.

Department of Energy, Mines and Resources

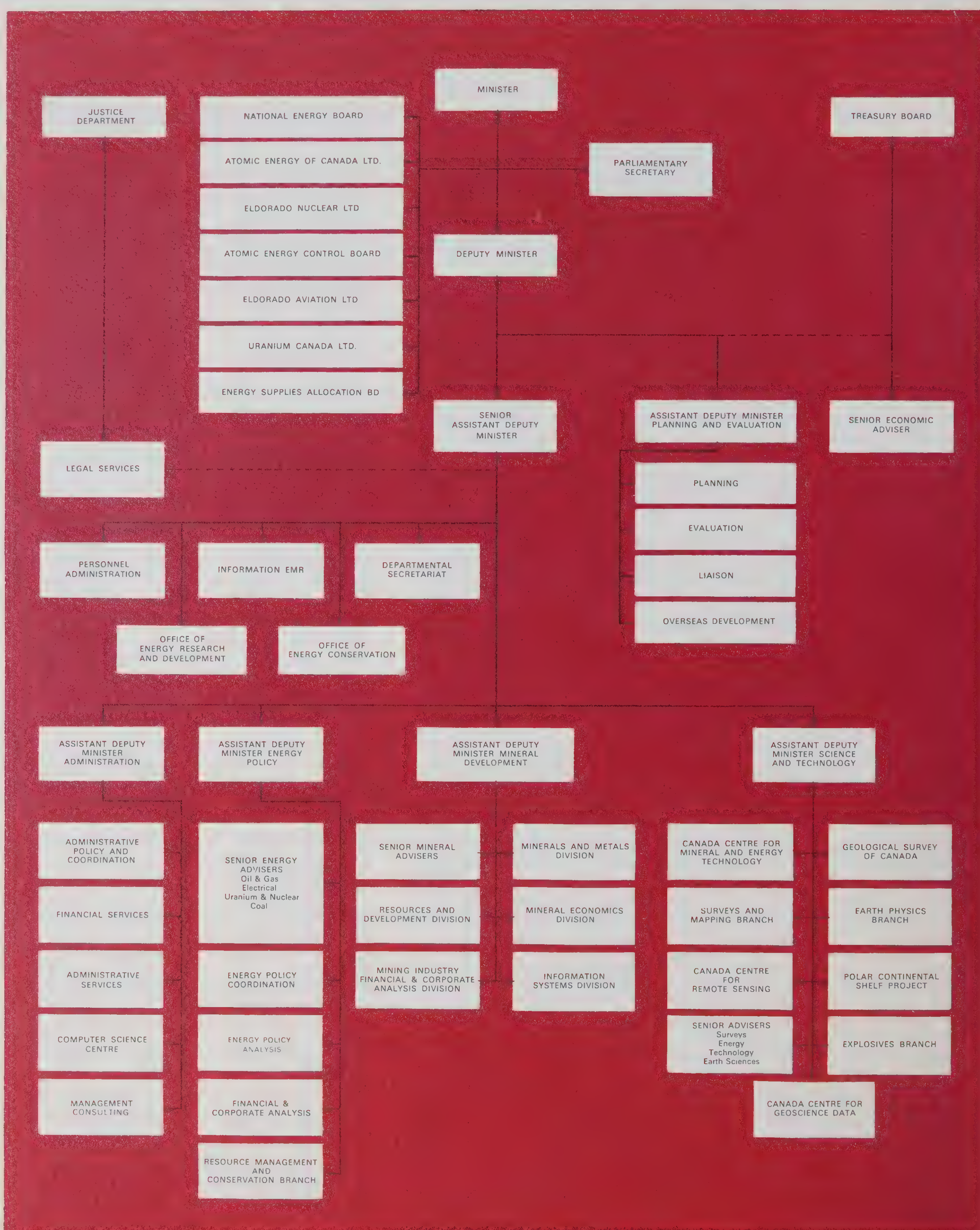
1974-75 Expenditures in thousands of dollars and man years

DEPARTMENTAL TOTAL: $557,722*
3,750,5 MAN YEARS

*Oil subsides $467,213



Department of Energy, Mines and Resources



Geological Survey of Canada

For the Geological Survey of Canada, 1974-75 marked still greater involvement in the search for a broader and more secure resource base for Canada, an effort that is spurred on (and complicated) by the deteriorating energy situation and the increasingly evident need to conserve the natural environment.

Along with the studies aimed more or less directly at uncovering more abundant sources of energy and of raw materials, the Geological Survey also expanded its terrain investigations to provide planners with a better appreciation of the capacity of various terrain types — especially in the Arctic — to support exploration, transportation routes, and new communities.

Such field studies rely heavily on the continuing imaginative support of laboratory investigations at the Survey's three main establishments — Ottawa, Calgary, and Dartmouth.

The total budget allotted to the Geological Survey in fiscal year 1974-75 was $21,744,000, of which approximately $5 million was spent on field work. A major share was also taken up by the Federal-Provincial Aeromagnetic Surveys, a cooperative project supervised by the Survey for a number of years. In 1974-75, the federal amount spent on these surveys was $1,275,000.

Probably the most significant new project launched by the Survey in 1974, again in cooperation with the provinces, is the Federal-Provincial Uranium Reconnaissance Program. This program was agreed to in principle in December, 1974, by the Canadian Ministerial Conference on Mineral Policy, provided that agreements are negotiated with each province individually.

The program is a response to the growing demand for uranium, both for domestic consumption and for export. Recent forecasts show that total world demand will outstrip production of this reactor fuel from present producers in the early 1980's, possibly by 1980. There is a lead time of about eight years between the discovery of a uranium deposit and production from it, and it is evident that the uranium reserves of Canada should be expanded without delay.

The objective of the program is to provide the exploration industry with high-quality reconnaissance data, and to provide governments with nationally consistent systematic information for the appraisal of Canada's uranium potential.

Although much of Canada has been explored for uranium, the methods used were often lacking in sensitivity and uniformity. Modern equipment and data-processing machinery are expected to produce much more accurate and meaningful results.

Two main methods will be used in the uranium program, which is expected to last approximately 10 years. Instruments installed in aircraft will measure gamma-ray spectra over those parts of the country that are relatively flat, with some outcrop and relatively thin overburden. This would be the case over much of the Canadian Shield. Geochemical studies on the ground will be carried out in mountainous terrain (where low-level flying is impractical) and in areas of thick sedimentary cover, as in the Prairies.

It is expected that much of the field work will be contracted out. The preliminary federal expenditure on the uranium program for the fiscal year under review was approximately \$110,000, with an additional outlay of \$315,000 for the gamma-ray spectrometry studies (this latter expenditure is included in the \$5 million already mentioned for field work). The total amount expected to be spent on the uranium program in 1975-76 is approximately \$1,545,000.

Another interesting project undertaken during the year by a Geological Survey team was a study of breccias, facies changes, and mineralization in Devonian rocks of the northern Rocky Mountains in northeastern British Columbia. Discovery of zinc and lead deposits in brecciated Middle Devonian carbonate rocks at Robb Lake, B.C., similar to those at Pine Point, N.W.T., caused speculation on the possible existence of a northern Rocky Mountain lead-zinc belt. Considerably more exploration and detailed geological work are required before these speculations are adequately tested.

The approach followed by the survey group is to try to determine for both the Robb Lake area in the mountains and the Pine Point-Great Slave Lake area in the plains what the history of the host sedimentary rocks has been. Such studies collectively make up what is known as sedimentary basin analysis, and are of outstanding importance to exploration for petroleum or base metals and for assessment of the rocks of the basin as hosts for these resources. Of particular interest in the study of the British Columbia breccias is the fact that exploration geology in the region was originally started and conceived in the 1950's for petroleum exploration, but has now turned out to be of vital interest in the search for strata-bound base metals. Thus basic geological exploration, properly carried out, has a permanent value and may serve several purposes.

A project to investigate the processes and effects of coastal erosion and sedimentation under Arctic conditions was commenced in the Sound between Byam Martin and Melville Islands in the District of Franklin, N.W.T., above latitude 75°N. Such geoscientific information is needed to assess the feasibility of inter-island gas pipeline routes. In addition, the work should elucidate the recent geological history of the area and provide Arctic sedimentary facies models. Particular attention was paid to the hazards to pipelines of scouring by "keels" of ice, particularly at the interface between land and sea.

A discovery of particular interest arising from this study was the effect on the frost table of sedimentary deposits. Well-developed beaches were found to be common along much of the coastline; in areas where beach sediments were composed of finer material and well-sorted sand, the frost table tended to lower to depth of up to 2 m (6′ 6″), whereas in the poorly sorted sand and fine gravel of the beaches its depth was no more than about 0.5 m (20″). Ice push may play an important role in contributing new sediment to the beach. It was also observed that offshore ice push may be a mechanism for originating new beach and lagoon systems — all of which could have a bearing on selecting the location for pipelines.

Recent oil and gas exploration in the Arctic has created the need for detailed information on the unconsolidated deposits, landforms, permafrost, ground ice, organic cover and the geomorphic processes responsible for terrain modification. To meet these needs a surficial geology inventory of Banks Island, District of Franklin, in the Western Arctic has been undertaken. The project was designed to obtain data that would aid in the implementation of territorial land-use regulations and be pertinent to engineering construction, petroleum exploration and related activities such as construction of overland pipelines. Field work during the 1974 season on this project was concerned with identifying and obtaining general information on the various unconsolidated lithological and stratigraphic units in the area, gathering quantitative data at critical sites, and attempting to understand the recent geological history of the island. Research was also undertaken to identify and describe the various processes acting on the geology of the region under study, and classifying its vegetation.

By studies such as this terrain inventory mapping can be carried out to determine the nature of the surficial deposits as a basis for "zoning" the land for future use, with emphasis on the environmental protection of the delicate permafrost.

Once again, *CSS Hudson* steamed out from the Bedford Institute of Oceanography in Dartmouth, N.S. to undertake marine geological studies for the Geological Survey. The primary purposes of this latest expedition were to undertake detailed studies of Lancaster Sound between the north of Baffin Island and Devon Island with particular reference to the rich sedimentary deposits, some of which may be oil-bearing. In the same area, a joint venture was undertaken with industry to evaluate the use of the Bedford Institute rock core drill in the Arctic environment and to carry out a program of bedrock drilling — some useful cores were obtained. Another project, undertaken in cooperation with the Polar Gas Consortium, resulted in seismic measurements being made in Barrow Strait to evaluate possible pipeline routes. Extended studies in the Labrador Sea – Davis Strait area increased knowledge of the marine terrain and tended to confirm the drifting apart of Greenland and Baffin Island.

Canada Centre for Mineral and Energy Technology

The Mines Branch, a research laboratory and pilot-plant complex, underwent a massive reorganization during 1974-75 and has changed its name to the Canada Centre for Mineral and Energy Technology (CANMET). The new name is designed to highlight its research in the energy field and to reflect its wide range of mining and mineral interests.

The former Mines Branch divisions and research centres were reorganized into four main laboratories — energy, mining, mineral sciences, and physical metallurgy. They attack major problems faced by the mineral industry to ensure the effective extraction and utilization of Canada's minerals and fuels. Their activities are planned and implemented through three programs: energy research, mineral research, and minerals energy and information.

CANMET's research and development work reflects today's demands for energy conservation, new sources of energy and a clean, attractive environment. As most of Canada's high-grade and readily accessible mineral deposits are already being mined, research emphasis is placed on developing recovery techniques for ores characterized by low-grade and complex mineral composition. CANMET includes about 700 scientists, technicians and support staff and last year operated on a budget of $14,779,000.

In 1974-75, fuels research was accelerated in efforts to extend existing reserves and to discover new sources of energy. Fuels research includes comprehensive evaluation of Canada's fossil fuels and the examination of refining methods for the low-grade petroleum of the Athabasca oil sands. The enormous potential of the sands cannot be tapped on a large scale until more efficient, economical techniques are developed for separating the oil from the sand and upgrading it for commercial use.

According to a report from the Alberta Energy Resources Conservation Board, Alberta's conventional crude oil reserves, representing the bulk of proved domestic oil supplies, contain less than 13 years' supply at present rates of consumption. This disclosure stresses once again the necessity of developing Canada's low-grade oil resources.

The refining of these resources is complicated by the presence of unwanted minerals, metals and sulphur. CANMET fuel experts have developed a thermal "hydrocracking" process that removes virtually all of the minerals and metals, reduces sulphur content, eliminates the production of waste coke, produces a high-quality distillate oil and increases the fuel yield by about 10 to 15 per cent. A proposal has been made to have Great Canadian Oil Sands test the hydrocracking process in the near future.

Growing energy needs, coupled with rising prices of oil and natural gas, have made coal an important future source of thermal power, especially in the coal-rich western provinces. CANMET is working on a federal-provincial project to determine the amount and quality of lignite coal in the Ravenscrag formation of Saskatchewan. About 3,000 samples have been analyzed and the results could mean development of a vast, alternate source of energy.

CANMET fuel experts are also exploring the feasibility of producing synthetic natural gas from coal, especially in regions of Canada that are short of natural gas but rich in coal resources. So far, researchers have estimated the lowest cost of producing natural gas from coal using existing technology. This estimate will be used to determine whether the production of synthetic natural gas is an economical alternative to other energy forms.

In efforts to promote the use of combustible wastes as an alternate source of energy, CANMET has given technical advice to the Ottawa Master Plan Study, headed by the Department of Public Works which is investigating ways of using municipal garbage as fuel to heat government buildings. CANMET staff are also providing expertise to a Canadian consortium that is proposing a plant fueled partly by municipal refuse to supply a paper mill with electricity and process steam. In addition, CANMET experts are participating in Canadian and international committees to promote the use of waste heat from thermal power stations for residential and commercial heating via district heating systems.

Apart from developing new sources of fuel for the future, CANMET is also engaged in a program to make more effective use of Canada's finite oil reserves. To aid in the more efficient use of home-heating fuel oil, CANMET developed a "blue-flame" oil-furnace burner. It is designed to reduce fuel consumption by about 10 per cent and is virtually non-polluting. Researchers are also monitoring furnaces to study the effects of conservation measures such as thermostat cutback, increased operating time and heat reclaimers. One experimental device that automatically closes off the chimney when the burner is not operating promises a substantial fuel saving.

Transporting liquid fuels through pipelines is another area of CANMET expertise. In future, much of Canada's oil and natural gas will come from the Arctic and pipelines able to withstand abuse from severe cold will be a necessity. CANMET metallurgists are testing pipeline metals for strength, weldability, corrosion, cracking, brittleness, and ductility to select the best materials for the job. Their evaluations will be used to determine the structural soundness of proposed pipelines for use in the harsh Arctic environment.

Mining research is aimed at maximizing ore production with minimum cost and environmental disturbance. In 1975, the third year of a five-year, $4-million project to optimize the design of rock slopes in open-pit mines was completed. The project is designed to reduce the excavation of waste rock from open-pit mines by more than ten per cent a year—a reduction of some 35 million tons that could save the mining industry up to $50 million annually. Now that the field work is almost finished, CANMET is assessing the data and is compiling an engineering manual on rock-slope design and maintenance.

Over the years, CANMET has conducted much of its mining research in cooperation with industry. One such venture has resulted in the design and manufacture of a lightweight, portable, diamond drill capable of drilling down to 1,000 feet. The entire rig can be dismantled, loaded aboard a Twin-Otter aircraft, unloaded and put together in less than four hours. This new type of drill assembly will reduce the cost of dismantling and reassembling equipment and of moving from one spot to another. The rig will also improve the efficiency of a drilling operation by eliminating much of the back-breaking labor of moving conventional rigs onto and around a site.

In another research project, CANMET teamed up with a major Canadian steel company to test a modified "shaft-electric furnace" under industrial conditions. The trials indicate that this novel smelting process lowers energy needs by about 30 per cent, alleviates pollution problems, increases output, and allows the use of coal as a source of carbon instead of the more expensive coke required for blast-furnace smelting. Energy needs are reduced in this process because the off-gases from the furnace are used within the overall smelting process. Since the furnace can be operated economically in smaller units than is possible with blast furnaces, it can be used in small or medium-size steel plants located in areas where the population is too small to support a large, integrated steel works.

Other significant research related to steelmaking is aimed at finding substitutes for expensive and increasingly-scarce imported coking coal—an essential ingredient in the making of steel. Western Canadian coal could provide a major supply of coking coal but there are problems in transporting it economically to major steel producers in the East. One solution is to ship the coal in an oil slurry through a pipeline. In this way, thermal coal for use in electric generating stations and coking coal could be transported over long distances. CANMET researchers are studying methods for separating coal from such coal-oil slurries without deterioration of its coking characteristics.

In another area of endeavor, CANMET has launched a joint program with the U.S. Bureau of Mines to determine the feasibility of producing aluminum from sources other than bauxite. Research indicates that a variety of raw materials such as anorthosite hold promise of freeing the Canadian aluminum industry from its dependence on expensive foreign supplies of bauxite.

Mine safety is a major and growing concern of CANMET and efforts have been stepped up to create an acceptable working environment free from dust, radiation, noxious gases, noise and excessive heat. At CANMET laboratories in Ottawa and Elliot Lake, scientists are testing a variety of techniques to measure and control the harmful components of mine air. In cooperation with the Mines Accident Prevention Association of Ontario, the Elliot Lake laboratory has modified a dust sampler to give a more accurate reading of dust levels in metal mines. These instruments are being tested in several mines.

Particulate emissions from diesel engines used in underground mining are also being studied to determine the effectiveness of water scrubbers and afterburners in removing harmful carbon particulates. Test results will be used to improve mine-ventilation design. CANMET scientists are also experimenting with thermal-infrared scanning devices for an early-warning detection system to prevent explosions.

In the field of mineral sciences, a wide range of studies are being carried out to determine mineral characteristics important to the extraction and processing of ores. CANMET researchers are using a sophisticated, image-analyzing microscope to assess rapidly and accurately the proportion of each mineral in an ore sample and the size distribution of these minerals. Tasks that were formerly complicated and time-consuming to perform have become routine with the "image-analyzer". In one project, it was used to determine the quality of the Peace River iron ore deposits in northern Alberta. The results of these investigations will help to determine whether a steel mill is established at the site.

More than 30 per cent of CANMET's research budget is assigned to various projects related to environmental improvement. One of the goals of the Centre is to develop new methods of processing and recovering mineral resources to reduce environmental problems. In 1974-75, research continued on hydrometallurgical methods of processing sulphide ores that avoid the sulphur-dioxide pollution caused by conventional smelting processes.

CANMET metallurgists have developed hydrometallurgical processes for extracting copper, nickel and cobalt from complex sulphide concentrates to produce crude or refined metals. The sulphur produced as a by-product is non-polluting and has commercial potential. Such processes could prove especially useful when the size of an ore deposit is too small to justify the cost of building a conventional smelting complex. A plant using hydrometallurgical processing could be built at the mine site.

In another area of environmental research, studies are continuing on converting mineral wastes into useful products. Processes have been developed for: the manufacture of foamed insulation from waste glass, the production of fertilizer from cement-kiln dust and lime tailings, the production of wood fibre and filler clay from the waste sludge of paper plants, the production of mineral-wool insulation from asbestos tailings, the manufacture of dry-pressed brick from iron-mine tailings and the production of calcium-silicate building bricks from the residues of magnesium-metal production. CANMET scientists are also studying methods of recycling cans from municipal waste to reclaim tin and steel components.

Unfortunately, most mineral wastes cannot be converted into useful products. To minimize the environmental effects of these wastes, CANMET researchers are studying a variety of methods for removing harmful substances from mine effluents and tailing ponds before they enter drainage systems. Tests have been conducted in northwestern Quebec on the contamination of water by tailings from ore processing mills. Tests have also been carried out on the tendency of certain clays to absorb polluting traces of metal from mine waste waters. During the year research continued on the revegetation of mine wastes to restore spoiled areas to their natural state. Revegetation prevents erosion by wind and water and reduces the polluting effects of airborne dust and seepage water. Field studies have been conducted on acidic mine tailings in the Elliot Lake area to determine the most suitable vegetation and fertilizers for soil and weather conditions.

Earth Physics Branch

The Earth Physics Branch during 1974-75 continued to employ the most modern automatic techniques to further develop a quick and efficient data gathering and relaying system for a variety of geophysical information. Emphasis was on projects for regions of resource exploration and development in Canada.

The branch studies the seismic, gravitational, geothermal, geodynamic and geomagnetic properties of the Canadian landmass and their relationship to similar data from around the world. These basic geoscience services provide key information for resource development, energy transportation, navigation, telecommunications and national defence and contribute to knowledge of the geological evolution of Canada and geological hazards such as earthquakes. As part of its routine work the branch also maintains a network of seismic, geomagnetic and earth motion observatories across Canada and produces maps of the gravity and geomagnetic fields.

During 1974-75, the branch operated on a budget of $5,490,000, of which $1,628,000 went to the Gravity Division; $1,524,000 to the Division of Geomagnetism; $1,635,000 to the Seismology Division and $703,000 to administration.

The Seismology Division began operating the Eastern Canadian Telemetered Network during 1974-75 with outstations at Manic 5 (Lac Manicouagan), Montreal, Maniwaki and Ottawa. Seismic signals, detected by the network, are transmitted to the Ottawa data laboratory in digital format over telephone lines. The network records seismic events in eastern and northern Canada, concentrating on the Ottawa and St. Lawrence valleys. In Ottawa, a computer analyzes all the data transmitted and, if the event is above a set intensity, stores it for future use. Ottawa will also now receive and store via a new telephone hook-up the date, time, period and amplitude of seismic events detected by CANSAM Canadian Seismic Array Monitor (CANSAM) in Yellowknife, N.W.T. The Yellowknife array is designed to aid in research on the capability to monitor and discriminate seismic events of a natural or nuclear nature from around the world.

A special study, by branch seismologists, of the La Malbaie area on the north shore of the St. Lawrence River in 1974-75, produced important data that will help outline the seismic patterns between Quebec City and La Malbaie and serve the continuing need to understand the physics of earthquakes. The site, a large meteorite crater, is the location of the highest seismicity and largest earthquakes recorded in Canada. Thirty events were detected in the project.

Drilling for studies of geothermal energy at Meager Creek near Lillooet, B.C. in 1974-75 revealed water under pressure and at a temperature of 60 degrees C. The site is well known as a source of many regional hot springs. Scientists hope to eventually outline the hydrology of the area, determine the cycle of temperature changes and, ultimately, find the source of the hot water.

Scientists studying permafrost in Canada's Arctic have managed to preserve the most northerly exploration well in the world—the Gulf-Neil well north of Greely Fiord, western Ellesmere Island. The well, first developed as a wildcat oil well, was preserved by inserting a cement plug down to permafrost and replacing the drilling mud with non-freezing fluid. The initial log, taken in 1974, showed that the permafrost depth at the site was 365 metres and logs taken over the next three years will show how the area settles back to thermal equilibrium following the disruption of the permafrost area around the drill site. In other permafrost work, researchers completed drilling studies to show a profile of permafrost on the shore line and offshore from Little Cornwallis Island. The data will be of use to mining companies in the area as permafrost provides an effective seal against sea water seepage and is an important factor in environment protection.

The Gravity Division last year began a program of analyzing subsidence patterns within several large North American sedimentary basins that will lead to a better understanding of general basin development. Initial results from the first study, conducted for the Sverdrup basin in the Canadian Arctic Islands, indicate that basin evolution may be broken into a series of cycles, each beginning with high subsidence rates accompanied by thick deposits of sediments and tapering off until interrupted by the start of the next cycle of subsidence. The periods of high subsidence rates at the beginning of each cycle appear to be contemporary with the uplift of areas around the basin perimeter. The uplifted region seems to migrate several kilometres toward the basin centre during the ensuing 10-30 million year period of the cycle.

During 1974-75, the Gravity Division program of mapping the Beaufort Sea at six kilometre intervals neared completion. This long-term project has produced reconnaissance gravity data of use as a framework from which exploration firms, particularly those searching for oil, can select areas for more concentrated study and from which models of the geological structure of the area can be constructed. The division also began a 10-year survey of James and Hudson bays under the same program of mapping Canada's gravity field. This is a cooperative program with the Canadian Hydrographic Service, Department of the Environment.

A new automated geomagnetic observatory at Yellowknife, N.W.T., began operation under the Division of Geomagnetism, in July, 1974, bringing the number of stations observing variations in the geomagnetic field across Canada to 11. Yellowknife lies under the auroral zone where the greatest number of variations in the external geomagnetic field occur.

Paleomagnetic studies from 1974-75 indicate that the Grenville geological province, which makes up the eastern section of the exposed Canadian Shield, may at one time have evolved separately from the rest of the Precambrian landmass. The orientation of the earth's magnetic forces is constantly changing and paleomagnetism—the study of this orientation in ancient time—is an important clue to geologic time and landform evolution. The alignment of magnetic particles in the ancient rocks of Grenville province is different from the rest of the Precambrian landmass, indicating that plate-style motions may have caused the sea to open and close, separating the two landmasses from 1,250 to 1,000 million years ago. In other paleomagnetic studies, the path of the magnetic pole (which appears to wander owing to the changes in geomagnetic orientation) 2,200 to 1,800 million years ago was established and an analysis of geomagnetic polarity for the Phanerozoic was completed.

In the early spring of 1974, the Division of Geomagnetism operated six recording magnetometers simultaneously in a line extending from Banks Island west 270 km into the Beaufort Sea, over the continental shelf and slope to the deep ocean. This area contains a remarkably widespread anomaly in the earth's magnetic field, and scientists hope that further analysis of the data will provide a reasonable explanation for this. The division has been concerned about the area since 1962 when the first records received from the region's main observatory at Mould Bay on Prince Patrick Island were so unusual that researchers suspected something was wrong with the instruments. Even during magnetic storms, when other Arctic observatories recorded rapid changes in all elements of the geomagnetic field, the trace of the vertical component at Mould Bay remained smooth. Different types of instruments showed the same effect leading to the conclusion that rapid changes in the vertical component of the magnetic field are cancelled here, to a large extent, by electric currents induced in some highly conductive body in the earth's crust below the Mould Bay observatory. Between 1963 and 1970, temporary magnetic recording stations on other islands of the Arctic Archipelago showed that the anomaly of supressed magnetic variations was not limited to the Mould Bay region but covered an area of at least 600 km north to south and 300 km east to west. A preliminary analysis of the 1974 records indicates no sharp western boundary of the anomaly and no clear relationship to the continental shelf.

An airborne magnetic survey was completed by the division over Manitoba, Ontario, Keewatin, Hudson Bay and Western Quebec in 1974. Total distance was 50,000 line-miles and data will be used to keep magnetic maps and charts up to date. Similar data, gathered during the past few years for western Canada, have been used to delineate major magnetic regions for this area and, in addition, to construct a special model interpreting a large-scale anomaly near Fort Nelson, B.C.

Canada Centre for Remote Sensing

The Canada Centre for Remote Sensing (CCRS) coordinates airborne and satellite remote sensing in Canada and promotes its use among other government bodies, universities and industry. Operating on a budget of $6,674,000, the Centre carries out research in remote sensing technology, develops applications for remotely-sensed data with other agencies, and makes the results available to users for the management of Canada's environment and natural resources.

Early in 1975, the CCRS awarded a major contract valued at $1.4 million to MacDonald Dettwiler Associates of Vancouver to build and install ground data-handling equipment at a new satellite receiving station at Shoe Cove, Nfld. Beginning in June 1976, the station will receive, record, process and distribute satellite imagery of Newfoundland and a large segment of the North Atlantic Ocean.

By virtue of an agreement between the CCRS and the National Aeronautics and Space Administration (NASA), the station will acquire imagery from three NASA satellites: the Earth Resources Technology Satellite (ERTS), launched in 1972 and now called LANDSAT-1; NOAA-3, a weather satellite launched in 1973; and LANDSAT-2, the second of a series of earth resources satellites, launched on January 22, 1975. Once the station in Shoe Cove becomes operational, it will supplement the services provided by the station in Prince Albert, Sask., which receives imagery for all of Canada except for the extreme Arctic and Newfoundland.

The airborne arm of the CCRS flew over 131 missions during 1974-75 for a total of more than 22,000 line-miles. Requests for the projects emanated from federal and provincial-government agencies, universities and private industry. Airborne imagery was sold to users at a cost per line-mile ranging from $5.50 for the first-time user to $14 for federal government users.

The fleet of four aircraft operated by the Centre includes two DC-3's, a Falcon Fanjet and a Convair 580. The interior of the Falcon was redesigned during 1974-75 to improve operating conditions and to eliminate power failures. Excess wiring, equipment racks, original seating and a bulky film printer and cooling system were removed and replaced by two new equipment racks and seating that allows three technicians to operate the entire sensor package. An infrared line scanner was fitted into the nose of the aircraft and each operator position was equipped with improved telecommunications facilities and a closed-circuit television screen.

The Convair 580 was purchased early in 1975 to satisfy the growing need for aerial surveys of the Arctic and Canada's coastal areas. The aircraft will be extensively modified during the year to accommodate current remote sensors and those of the future with all-weather capabilities. The aircraft should be at the disposal of users late in 1975.

The Centre also acquired an Airborne Data Acquisition System that was installed in one of the DC-3's. This computerized device monitors and records information from various sensors and navigational systems on magnetic tape. A "quick look" system on the ground is used for playback, display, and preliminary analysis of information from the system.

In keeping with its policy of encouraging the development of a commercial remote sensing enterprise in Canada, the Centre issued a three-year contract valued at $2.5 million to Innotech Aviation of Montreal to operate and maintain the aircraft used for airborne remote sensing—services formerly provided by the Canadian Forces Airborne Sensing Unit. Interra Environmental Consultants Limited of Calgary, MacDonald Dettwiler Associates of Vancouver and Lavolin Associates of Montreal will work with Innotech as subcontractors. These companies eventually will provide the full range of remote sensing services from the acquisition of airborne imagery to its processing and analysis.

An important part of the Centre's function is to determine the benefits of remote sensing for Canada and to assist users in implementing remote sensing methods that are beyond the research stage but are still not commonly used. One of the most promising uses of satellite imagery that emerged during 1974-75 was in the field of Arctic navigation. A "quick-look" facility attached to the satellite receiving station in Prince Albert, Sask., provides black and white photographs of Arctic sea-ice within 20 minutes of LANDSAT's pass over Canada. The photographs are then relayed to Ice Forecasting Central, a division of the Department of the Environment in Ottawa, which updates its ice charts the same day and transmits the information to ships. In this way, ships can circumvent the ice, avoid costly delays and save thousands of dollars.

Geophysical Service, a company doing seismic work in the Arctic as a preliminary step in the search for oil, equipped two of its ships on an experimental basis to receive the "quick-look" imagery directly from Prince Albert. The Canadian Navy followed suit with one of its ships. The satellite imagery gives a general picture of sea-ice conditions and is used to supplement the visual observations made from aircraft patrols.

LANDSAT imagery is also a practical, inexpensive method of locating and monitoring new forest fires and burned-out areas and assessing the damage to vegetation. In 1975, 45 forest fires were located in the isolated regions of northern Saskatchewan using LANDSAT imagery. In one burned-out area near Stoney Rapids, Sask., it was estimated that about 10 hours of flying time by helicopter would have been necessary to map the damaged area. LANDSAT imagery provided the information within minutes.

A study conducted during 1974-75 of Yellowknife, N.W.T. demonstrated that the least expensive method of mapping forest fires was by transferring the satellite data in print format to an existing map. The researchers concluded that $10,000 and six man-months would be required to map and monitor this area using LANDSAT imagery.

The mapping of areas susceptible to landslides is another field that can benefit from airborne remote sensing. During 1974, researchers at CCRS studied a region of eastern Ontario covered by leda clay, a porous soil that is extremely sensitive to natural or artificial disturbances. They discovered that aerial photographs of the area spanning decades were valuable for monitoring environmental changes that could provide clues as to the present and future status of the land. Information about the environment could be extracted from remotely sensed data to determine the area's susceptibility to landslides. In fact, the researchers concluded that landslide inventories and susceptibility mapping could be achieved practically and economically only by employing remote sensing techniques. Landslide inventory maps can be used by regional planners to direct high-density settlement away from these areas, to route traffic corridors through safer districts and to plan reforestration projects that will stabilize such terrain.

Remote sensing is a highly-automated, complex technology that is constantly being modified to meet the needs of users across the country. One sensor being evaluated by the CCRS is a laser fluorosensor. It is a device used at night for identifying and mapping the distribution of oil spills, water pollution, chlorophyll, algae and tracer dyes. It operates by exciting these substances with an ultra-violet laser and detecting their fluorescence. The laser's intensity can be altered so that the sensor also can determine water depth over clear or shallow lakes, rivers or coastal waters by measuring the time interval between pulses reflected from the surface and bottom.

Another sensor undergoing extensive testing is a microwave scatterometer that emits microwaves and measures their "backscatter" from the ground at different angles. It provides information about sea state and ice type that can be used to infer ice thickness. Such information could be transmitted to ships in the ice-infested waters of the North to reduce the hazards of Arctic navigation.

Evaluating new equipment for more efficient processing and analysis of satellite imagery is another concern of the CCRS. The Image 100 system, acquired in April 1974, has swept the Centre into a new era of LANDSAT imagery analysis. This system automatically analyzes a LANDSAT image line by line and point by point and categorizes its content according to a classification scheme devised by the interpreter.

For example, from a digital tape an interpreter might select a portion of a scene, magnified or reduced, that he wishes to investigate. He then instructs the machine to show the image on its color television screen. Using carefully selected ground truth, the operator tells the machine that certain areas are fallow fields. Once it is fed this information, the machine instantaneously classifies the rest of the image. The fallow fields might appear yellow in contrast to the remainder of the screen. In this way, different types of vegetation, water and land use are distinguished and the classified images can be used to produce accurate topographic maps. The Image 100 also makes possible quick and accurate assessments of environmental change in specific areas over periods of time.

The CCRS also has modified a laser beam image recorder (LBIR), developed by the University of Toronto's Institute of Aerospace. This device is designed to produce satellite imagery in color more efficiently than the conventional method of producing satellite imagery from electron beam image recorders. During 1975, Canadian Aviation Electronics Ltd., of Montreal will complete engineering and installation of the LBIR and the Centre will tie the instrument into its computer system.

Polar Continental Shelf Project

Polar Continental Shelf Project (PCSP) continued to provide program coordination and support logistics to scientific researchers carrying out field activities in the Canadian Arctic; in the past season the expeditions supported ran the gamut from Archaeology to zoology. Although most of these field activities were on behalf of EMR and other government departments such as Indian Affairs and Northern Development, and Environment Canada, PCSP gave assistance also to scientific parties from 10 Canadian universities and to such far-flung foreign institutions as the Universities of Washington, Liège, Hokkaido and Uppsala.

For the 1974-75 fiscal year, the total budget of the PCSP was $3.2 million. Once again the base camps were maintained at Tuktoyaktuk on the North Shore and at Resolute Bay on Cornwallis Island. Field work was carried out between mid-February and mid-October.

In addition to the total of 73 regular Polar Continental Shelf projects of considerable diversity, PCSP supported 32 projects under the cooperative Industry Government Program in the Beaufort Sea. At times, unfavorable ice conditions kept scientific parties on shore, which taxed the facilities of the base camp at Tuk to capacity. The major field program efforts were concentrated in the hydrographic survey of Eureka Sound and adjacent fjords and the gravity survey of southern and eastern Amundsen Gulf. Permafrost and sea ice studies both received considerable support in the Beaufort Sea and Resolute areas.

The biological sciences were very well supported in 1974. Arctic fauna studied included whales, greater snow geese, caribou and muskox, polar and grizzly bears, and ringed seals. Other areas of interest included glacier physics, climatology, vegetation and marine biology.

Explosives Branch

The Explosives Branch administers the Canada Explosives Act and regulates all factories that produce commercial blasting explosives, military explosives, blasting accessories, gun-powder, sporting ammunition, and fireworks. The quality and safety of these products, as well as their road transportation, storage, sale and importation are controlled by a licensing system supported by inspections of division members. All licences are issued from the Ottawa office.

During 1974-75, the number of factories licenced to manufacture explosives dropped from 66 to 64. They produced 231,000,000 kilograms of commercial blasting explosives—an increase of 16,000,000 kilograms over 1973-74. The production of fireworks, ammunition and blasting accessories also increased but not to the same degree as commercial blasting explosives.

A bill to amend the Explosives Act was introduced in the Senate in November, 1974, and was passed to the House of Commons for clause by clause examination. The aim of the bill is to tighten control over the sale, purchase, possession and security of explosives, to reduce the incidents of abandoned explosives and to make the abandonment of an explosive an offence. The amendment also will result in stiffer penalties for infractions under the Act. It is expected that the bill soon will become law.

Since 1973, the Explosives Branch has provided courses to qualify candidates as "Fireworks Supervisors". During 1974-75 about 2,600 persons attended courses at centres across Canada.

Research Agreements

Through its program of research agreements, the department funds extramural research and development projects that are directly related to EMR's areas of concern. Organizations not directly managed by the federal government can apply for aid on behalf of research in the natural, physical and social sciences.

By means of research agreements, advice to government and information of value to other interested parties can be based on the research of expert specialists from a wide variety of fields, who frequently use a multidisciplinary approach. Assessment of proposals and follow-up on the progress of projects is the responsibility of the branch or branches of EMR whose disciplinary orientation relates most closely to the subject of the research.

Agreements are made for the next fiscal year. During 1975-76, 36 Canadian institutions will share funds totalling $882,670. The largest portion of this amount, $819,170, will go to 111 researchers who are members of university faculties; the balance will go to members of provincial research councils and specific research institutions.

Typical research projects approved this year include:

in situ recovery of oil from the Alberta oil sands;

Natta-Ziegler catalyzed Fischer-Tropsch hydrogenation reactions;

improvement of energy utilization in the Canadian transportation sector;

simulation of travelling waves on high voltage direct current transmission lines;

gasification of peat in a spouted bed reactor;

laser rock breakage;

Japanese economic growth and Canadian mineral exports;

regional metallogenic analysis of Nova Scotia: a multi-disciplinary approach;

Precambrian porphyry copper and molybdenum deposits in Ontario and Saskatchewan;

evolution of a "Greenstone" belt;

radio frequency interferometry as applied to ice and permafrost sounding;

map generalization;

urban cartography;

seismotectonic studies of Newfoundland.

Administration

The Administration Sector of EMR is comprised of a policy and coordination group, personnel, financial and administrative services, a computer science centre and a management consulting group. The personnel branch is concerned with recruitment, training, staff records, language training and preparation for retirement. By the end of the fiscal year, EMR had a full-time staff of 3,232, an increase of 96 over the preceding year. The department also employed a number of term employees, among them summer students, totalling 550 man-years during the fiscal year. The total man-year utilization for the fiscal year was 3,763, an increase of only eight man-years over the previous year. Approximately 85 per cent of the staff is employed in the National Capital Region; the others are employed in about 25 locations across Canada.

The department is strongly oriented toward the scientific, engineering and technical fields, with about 30 per cent in the scientific and professional category and a further 33 per cent in the technical category. About 1,200 or 37 per cent of the staff hold university degrees, of whom some 225 have master's degrees and 375 have Ph.D. degrees. This educational requirement in highly specialized fields makes the recruitment of staff a more than normally difficult process.

The department as a whole made considerable progress during the year in its ability to provide services to and to communicate with employees and the public in the official language of their choice, as a result of intensive language training programs and the recruitment of bilingually qualified personnel. By March, 1975, the number of qualified incumbents in bilingual positions was 406, which represented an increase of 52 per cent in bilingual capability over the previous year. To enable employees to retain and increase their capability in French the department is carrying on active monitoring and tutoring programs. Progress was achieved in the department's ability to make "work instruments" available to employees in either official language. New forms were published in both languages and considerable headway was made in translating unilingual documents into French.

The department's ratio of participation by members of the anglophone and francophone communities is 82 per cent anglophone to 18 per cent francophone, and plans are underway, in cooperation with the Public Service Commission, to give even greater emphasis in recruiting to the French-speaking scientific and professional communities. One of the programs is a cooperative program with the University of Sherbrooke involving the rotational assignment of French-speaking undergraduates between EMR and the university.

Financial Services provides financial advice to the whole department, develops accounting policy and procedures, coordinates submission of financial plans to Treasury Board, and carries out control and reporting functions. EMR's financial services differ from those of many other federal government departments in that they administer not only a headquarters but also an extensive field surveys budget; last year alone some 325 field accounts were operated in all parts of Canada, including the Far North. In addition the group also handles some of the financial matters for other agencies which report to Parliament through the Minister of Energy, Mines and Resources, such as Atomic Energy of Canada Ltd., Eldorado Nuclear Ltd. and Uranium Canada Ltd.

The most significant undertaking by Administrative Services during 1974-75, in addition to its day-to-day administration functions, was the move of employees into the new EMR Tower building at 580 Booth Street in Ottawa in the Fall of 1974. Close to 800 employees were moved in from various locations in different parts of the city, and others were relocated within the Booth Street complex. Administrative Services also looks after Technical Field Support Services, providing support for all EMR activities in the field. The inventory of vehicles numbers about 500, valued at over $5 million, and ranges anywhere from skidoos to all-terrain motorcycles, other supplies include scientific instruments, sleeping bags and emergency freeze-dried food rations—everything required to sustain an expedition in the field. Administrative Services also arrange for the chartering of aircraft and helicopters of all types, the annual outlay for which by all EMR branches is in the neighborhood of $6 million.

A central in-house management consulting service is provided, on request, to all areas of the department. Major projects carried out during the year were the development of an order processing system for the Canada Map Office, reorganization of publication distribution at Vancouver, and a workload analysis study at the Calgary Institute of Sedimentary and Petroleum Geology.

The gross budget of the EMR Computer Science Centre for 1974-75, which is operated on a cost-recovery basis with direct charges to users, was $2.8 million. The Centre performs systems analysis and programming, with related data manipulation and display functions. These services are offered to any government department that needs them; during the fiscal year under review, about 25 per cent of the work load was on behalf of departments other than EMR, who availed themselves, among other services, of a plotting facility which is unavailable at most other computer centres.